WOODLAND

AM
1946
WO

BOSTON UNIVERSITY
GRADUATE SCHOOL

Thesis

BIOLOGY AND CONTROL OF THE HOLOMETABOLOUS INSECT PESTS OF THE ECONOMICALLY IMPORTANT UMBELLIFERAE

BY

John Turner Woodland
(A.B., Boston University, 1945)

Submitted in partial fulfillment of the
requirements of the degree of
Master of Arts
1946.

AM
1946
WO

Approved

by

First Reader Norman S. Bailey

Second Reader Stuart K. Harris

TABLE OF CONTENTS

CHAPTER PAGE

PART I -- INTRODUCTION

I. THE PROBLEM

Definition of terms 1

Biology and control 1

Holometabolous insect pests 1

Economically important _Umbelliferae_ 1

Statement of the problem 8

Organization of remainder of thesis 9

PART II -- BIOLOGY AND CONTROL OF INJURIOUS SPECIES

II. COLEOPTERA 11

Elateridae 11

Meloidae 16

Chrysomelidae 20

Epitrix cucumeris Harris 20

Systena taeniata (Say) 23

Curculionidae 25

*_Listroderes obliquus_ Gyllenhal 26

*_Listronotus latiusculus_ Boheman 41

Scarabaeidae 47

Autoserica castanea (Arrow) 49

*_Ligyrus gibbosus_ (DeGeer) 52

Phyllophaga 57

CHAPTER PAGE

III. LEPIDOPTERA 62

Tortricidae 63

Archips rosaceana (Harris) 63

Pyralididae 66

*Phlyctoenia ferrugalis Hübner 66

Oecophoridae 86

*Depressaria heracliana (DeGeer) 87

Noctuidae 91

Agrotis c-nigrum Linnaeus 91

Agrotis unicolor Wlk. 93

Autographa brassicae (Riley) 94

*Autographa falcifera (Kirby) 97

Mamestra legitima Grote 99

Mamestra picta Harris 100

Papaipema nebris (Guenée) 101

Porosagrotis orthogonia Morrison 105

Xylomyges eridania Cramer 108

Arctiidae 109

Diacrisia virginica (Fabricius) 109

Papilionidae 112

*Papilio polyxenes Fabricius 112

CHAPTER PAGE

IV. DIPTERA 127

Anthomyiidae 128

Hylemyia brassicae (Bouché) 129

Trypetidae 135

*Acidia fratria (Loew) 136

Psilidae 142

*Psila rosae (Fabricius) 143

PART III -- SUMMARY

V. SUMMARY 170

BIBLIOGRAPHY 180

* denotes specificity for the Umbelliferae.

PART I. - INTRODUCTION.

CHAPTER I. - THE PROBLEM.

The biology and the control of an insect pest are intimately related. The term biology, as used here, refers to the structure, habits, and life history of the species under consideration. Only by a sound understanding of each of these factors is it possible to plan and carry out effective control measures.

All the insects discussed in this paper have holometabolous or complete metamorphosis. The young insect, or larva, which hatches from the egg is an entirely different form from the imago or mature insect. In order that the larva may become changed into the adult form, it is necessary for another stage - an outwardly quiescent stage - to be interposed between them. This stage is called the pupa. The pests to be described here belong to three of the orders of insects which undergo complete development. These orders are the Lepidoptera, the Coleoptera, and the Diptera. The only members of these three orders which will be considered at any length are those which are primarily pests of the economically important Umbelliferae.

The Umbelliferae constitute the Carrot or Parsnip Family, a group of herbaceous plants widely distributed throughout temperate and subtropical regions of the world. The name of the family is derived from its distinctive inflorescence, an

umbel, or flattened cluster of small flowers with stalks arising from a common point. In many forms each branch of the cluster branches in turn into a secondary cluster; such a plant is said to have compound umbels. Additional characteristics of the Carrot Family are its hollow, striate stems and alternate, usually compound leaves. The flowers of all the species are so much alike that the genera are determinable only by the fruit.

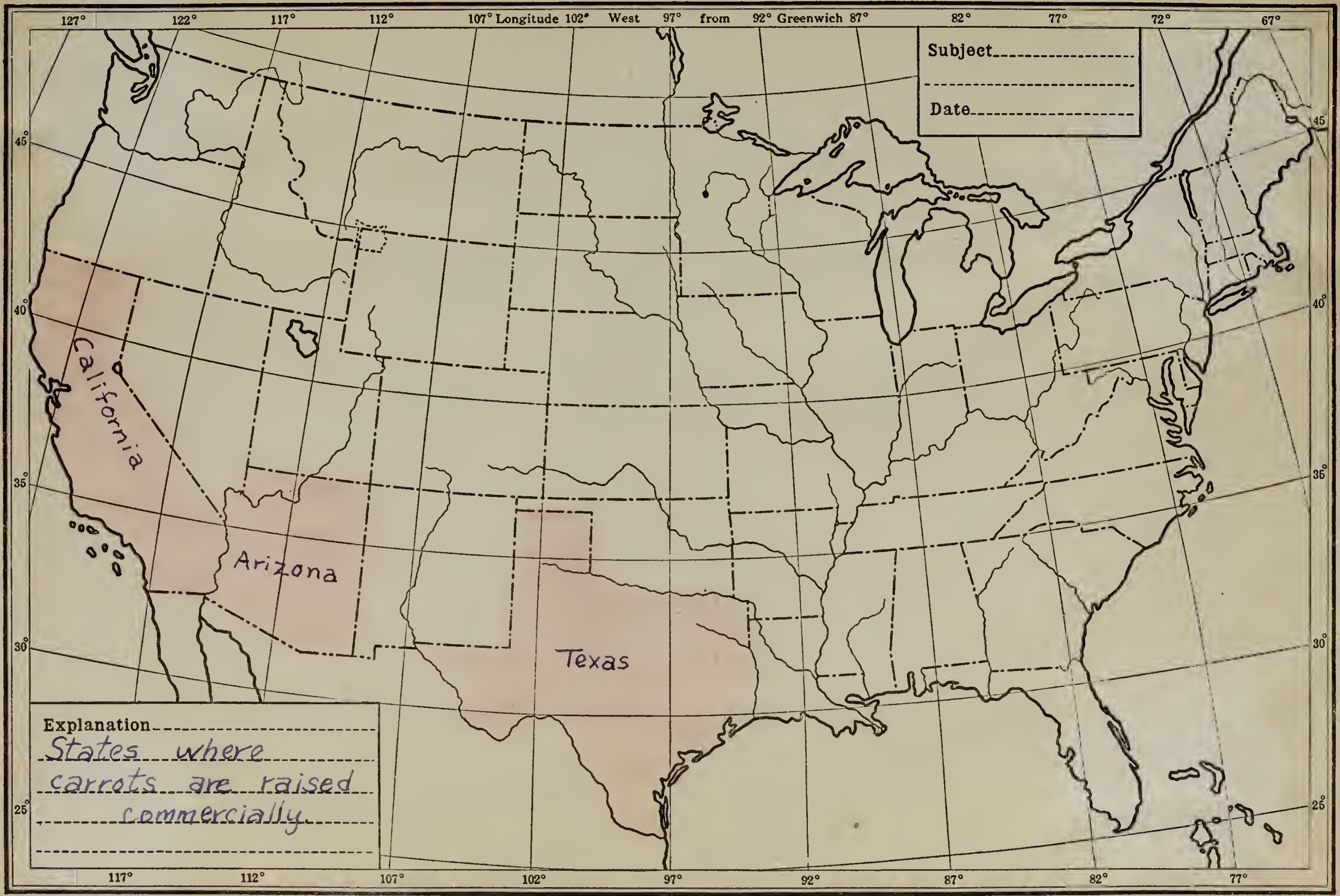
The only Umbelliferae of real economic importance in the United States are carrot, celery, parsley, and parsnip, all biennial herbaceous plants. The accompanying maps show the areas of the country in which these crops are concentrated. Parsley and celery are usually grown for their tender, flavorous foliage, while carrot and parsnip are grown for their long, thick sweet tap-roots.

Parsley, which is Petroselinum hortense Hoffm., is grown as an annual here. Its horticultural varieties are curled-leaved (var. crispum), fern-leaved (var. filicinum) and Hamburg or "rooted" (var. radicosum). The leaves of all of these varieties are used for garnishing and flavoring meat dishes, soups, and salads. In America the curled-leaved varieties are most popular, although the fern-leaved varieties are just as attractive. The Hamburg varieties are usually cooked like parsnips.

The crisp, blanched leaf-stalks of celery, which is Apium graveolens Linnaeus, make a dish in themselves. They

On the following page is a map showing the states where carrots are raised commercially.

McKinley's Geographical and Historical Outline Maps. No. 176b. The United States. (State boundaries.)



Subject

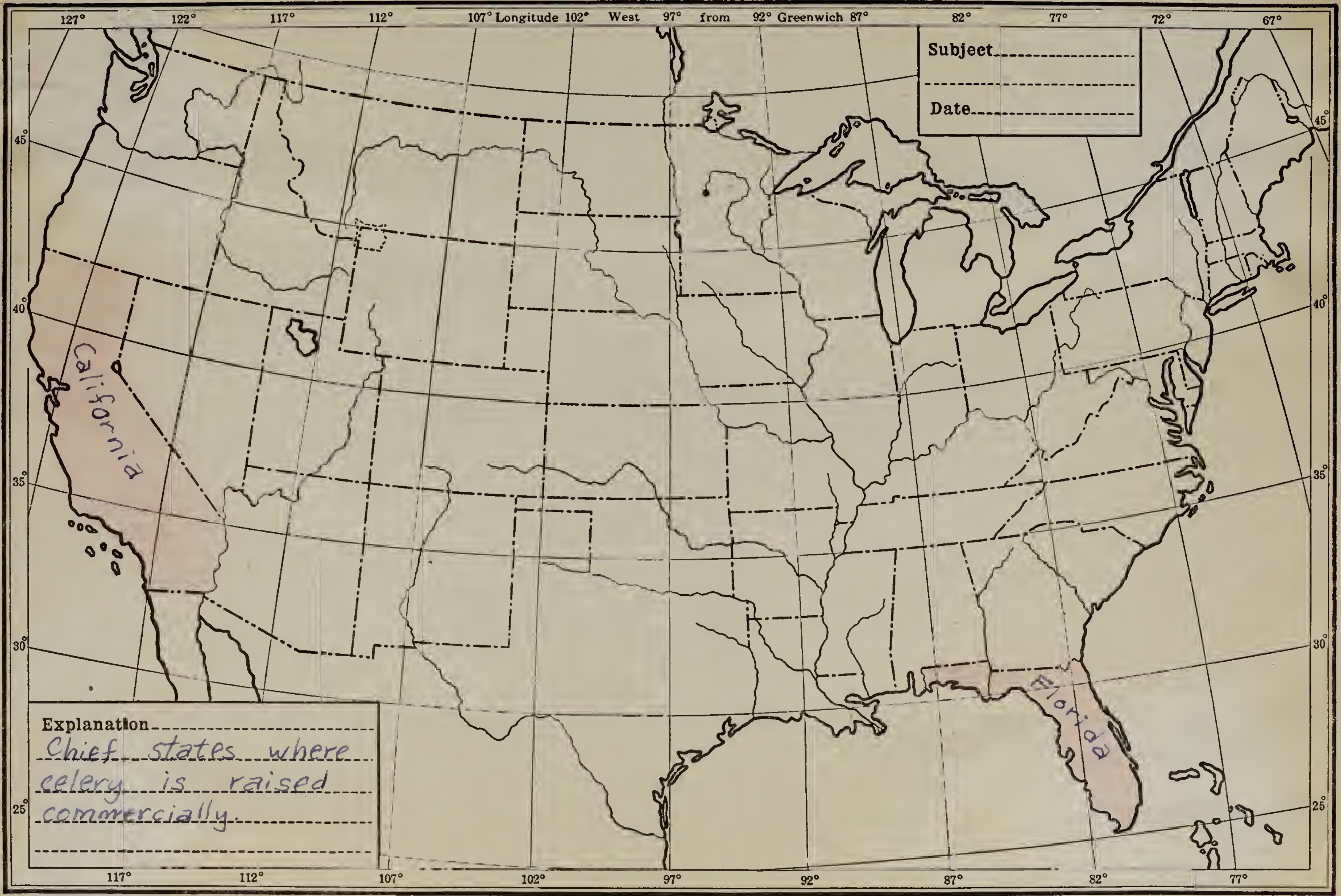
Date

Explanation States where carrots are raised commercially.

Copyright, McKinley Publishing Co., Philadelphia, Pa.

On the following page is a map showing the chief states where celery is raised commercially.

McKinley's Geographical and Historical Outline Maps. No. 176b. The United States. (State boundaries.)



Subject

Date

Explanation

Chief states where celery is raised commercially.

Copyright, McKinley Publishing Co., Philadelphia, Pa.

are often an important ingredient of salads and are also used for flavoring soups and stews. Commercial celery crops are grown chiefly on reclaimed muck lands. Celeriac is a variety of celery with stout, turnip-like roots. The Garden Encyclopedia (81, p.233) says,

> They may be sliced and eaten raw with salt, used for flavoring soups and stews, boiled like turnips and served with a cream or hollandaise sauce, or served as a salad with French or mayonnaise dressing.[1]

The uses of the carrot, Daucus Carota var. sativa Linnaeus, are familiar to all. In addition, there are large-rooted late kinds which are valuable for stock feeding. The numerous types of carrots vary all the way from the nearly spherical French forcing type to the well-known tapering "long Danvers".

The sweet white roots of the parsnip, Pastinaca sativa Linnaeus, are used in much the same way as are those of the carrot. One of their advantages is that they may be left in the ground until spring, as they are not injured by freezing.

Dill, anise, and caraway possess a slight and limited economic value. Anise is an annual herb, while caraway and dill are either annuals or biennials. The leaves and seeds of anise, Pimpinella anisum Linnaeus, are used to flavor cooking and in medicine and licquers. The tender young shoots and leaves of caraway, Carum Carvi Linnaeus, are sometimes used to flavor salads; the seeds may be used to flavor bread, cake, confections,and cheese. The bitter seeds of dill,

---

[1] Celery is Apium graveolens var.dulce and celeriac is A. graveolens var. rapaceum.

Anethum graveolens Linnaeus, are used to flavor the well-known dill (cucumber) pickles.

The problem of insect control on umbelliferous plants was for many years a comparatively insignificant one. Since the beginning of the twentieth century a combination of factors has caused it to assume increasing importance. In nature, plants of the Carrot Family are usually scattered rather thinly over large areas. The population of the insects which feed upon them is sharply reduced each time the destruction of only one plant or a little group of plants necessitates a search for another suitable group of host plants.

The pioneer farmer often provided a chance for the insects to multiply by concentrating their food supply in well-cared-for rows. But these farmers did not wholly depend upon any of the Umbelliferae. These crops did not constitute their basic food supply, but,rather, provided a pleasing variation. Consequently, as with the average home gardener of today, if their umbelliferous plants became seriously infested, they merely discontinued growing them until the insect population died down.

All these conditions were changed when the demands of modern industry made the commercial raising of umbelliferous crops profitable. One of the greatest demands for such vegetables as carrots came from the large canning industries which sprang up in the big cities. Carrots were not only a

valuable canned product in themselves; they also constituted an important ingredient of canned soups and stews,

As a result, in certain localities large areas have been planted to carrots in closely-set rows year after year. In these areas no longer do large numbers of insects periodically die in search of new host plants. Instead, under such ideal conditions they multiply rapidly and steadily. Furthermore, the regular market for carrots has made it undesirable to discontinue planting them when insect populations mount. Hence growers have had to face the problem of keeping insect numbers in check effectively and at the same time inexpensively enough to make business profitable.

In Part II of this work the holometabolous insect pests of the economically important Umbelliferae are discussed by orders. Within each order the families with members represented are arranged phylogenetically. Within each family the arrangement of the species is alphabetical, when two or more are considered.

The emphasis is placed upon those insects which are fairly specific for the Carrot Family. The general feeders concerned are mentioned in their proper places and references to the extensive literature written on them are made. It is highly improbable that any of these general feeders ever attacks umbelliferous plants alone. In any case, their identity does not long remain secret when an outbreak occurs. The control of them on members of the Carrot Family does not differ markedly

from their control on similar vegetables of other families. Certain warnings and suggestions which are stated in describing the control of the specific umbelliferous pests must, of course, be borne in mind when treating general feeders found damaging these plants.

The discussion of each pest which is treated in detail commences with an account of its distribution and a list of its host plants, both cultivated and wild. There follows a description of the appearance, habits, and duration of each stage of the life cycle, beginning with the adult. The nature and extent of the damage caused and the usual numbers of generations occurring each year are related.

The first control measures recommended are those which involve the manipulation of natural forces by man and the agricultural methods which he can use to his advantage. Insecticidal measures that may be resorted to complete the account.

PART II -- BIOLOGY AND CONTROL OF INJURIOUS SPECIES.

CHAPTER II. -- COLEOPTERA.

The beetles are the largest order of insects, for at the present time over 240,000 species of them are known. Their bodies, which generally appear rather thickset and heavy, are covered by a denser and tougher exoskeleton than is present in most other insects.

As a rule, beetles have two pairs of wings. The hard and horny front pair, called elytra, act as a protective covering for the large membranous hind pair. The elytra are not used in flight, and when the insect is at rest, lie flat on the back over the hindwings, which are folded beneath them.

The adults, as well as the larvae, which are often called grubs, have mouthparts suited for chewing. The pupae of most beetles have legs and wing pads which lie close to the body, but are covered by separate sheaths rather than enclosed in the shell that covers the rest of the body. This sort of pupa is called a pupa libera or an exarate pupa.

Five families of beetles contain certain species which will feed upon cultivated Umbelliferae. Only three of these species have not made themselves widely known as general feeders.

Elateridae (click beetles).

The click beetles are also popularly known as snapping

beetles, skipjacks, and spring beetles. All of these names refer to the peculiar manner in which these beetles right themselves when placed on their backs.

When click beetles are disturbed, they drop to the ground and lie on their backs, as if dead. They remain motionless with legs and antennae retracted. After some time they turn over and scurry away at great speed. The beetles may turn over in the usual way, but if the surface on which they are lying is even and hard, they resort to their snapping method. They are enabled to do this because they have a prosternal finger-like spine which extends into a mesosternal cavity or pocket. The prothorax and mesothorax are loosely joined. The beetles arch upward so that the spine is nearly withdrawn from the cavity. Then they suddenly relax, forcing the spine all the way back into the cavity. This action causes the rather elastic bases of the elytra to strike the surface with an audible click in such a way that the beetle is flipped into the air. If the beetle does not land right side up, it repeats the process until successful.

Click beetles may be recognized by the fact that the posterior angles of the prominent prothorax extend backward as sharp points. The beetles are slender, elongate, and flattened dorsoventrally. Their antennae are eleven jointed and often serrate.

The elongate, cylindrical larvae of the Elateridae are

known everywhere as wireworms. They possess a flattened chitinous head and a trunk composed of a series of segments all very much alike. These segments are covered by a very tough amber exoskeleton. Wireworms have no eyes but bear very short three-jointed antennae. The legs are poorly developed.

The feeding habits of wireworms are quite varied. Some feed upon decaying wood, others upon fungi. Numerous species are of economic importance because they attack the roots and seeds of crops. As a group, these species are commonly reported as injuring most grains and grasses and all garden vegetables. The carrot is the only umbelliferous plant found in any available lists of hosts. None of the lists which include the carrot pertains to any particular species of wireworm,[1] but a list of a few of the more important economic species follows:

Agriotes mancus (Say) (wheat wireworm)
Corymbites aeripennis destructor (Brown) (dry land wireworm of Dakotas)
Corymbites noxius Hyslop (dry-land wireworm)
Drasterias elegans Fabricius
Horistonotus uhlerii Horn (sand wireworm)[2]
Limonius agonus Say
Limonius californicus (Mann)(sugar-beet wireworm)
Limonius canus Leconte (Pacific wireworm)
Limonius ectypus (Say) (eastern field wireworm)
Limonius plebejus Say
Ludius pruininus noxius Hyslop (Great Basin wireworm)
Melanotus communis Gyllenhal
Melanotus cribulosus (Say)
Monocrepidius verpertinus Fabricius (Southern corn wireworm)[3]
Pheletes ectypus Say (field wireworm)

---

[1] Nearly all books and bulletins on the subject treat wireworms as a group or else discuss one particular species in its relation to one or two important host plants only.
[2] Also called corn and cotton wireworm.
[3] Also called cotton wireworm.

It is not an exaggeration to say that wherever crop plants are grown wireworms are to be found. They are said to be especially destructive in the irrigated lands of western United States. Although the carrot is the only umbelliferous plant reported to be attacked by wireworms, numerous other economically important plants are injured:

- apple
- barley
- bean
- beet
- buckwheat
- cabbage
- cauliflower
- clover
- corn
- cotton
- cowpeas
- cucumber
- eggplant
- endive
- lettuce
- lima bean
- mangel
- muskmelon
- oats
- onion
- pea
- peanut
- potato
- pumpkin
- radish
- rape
- rutabaga
- rye
- spinach
- squash (winter)
- strawberry
- sugar-beet
- sweet corn
- sweet potato
- timothy
- tobacco
- tomato
- turnip
- vetch
- watermelon
- wheat
- white pine

Flower garden and greenhouse plants attacked by wireworms are:

- aster
- carnation
- chrysanthemum
- columbine
- cyclamen
- dahlia
- gaillardia
- gladiolus
- gypsophila
- hop vine
- iris
- lobelia
- lupine
- pansy
- phlox
- pinks
- platycodon
- rose
- snapdragon
- stock
- sunflower
- sweet alyssum
- violet
- wallflower

In addition, wireworms feed upon such weeds as dandelion, plantain, wild mustard, wild radish,and wild rutabaga.

The economically important species of wireworms feed almost entirely in the soil on the seeds and roots of plants. Occasionally they bore upward into the bases of the stalks. Their

tunnels are usually less than one-quarter of an inch in diameter. Common wireworms require from one to six years to complete their life cycles.

Control. So many species of wireworms are injurious that cultural practices necessarily differ considerably in various parts of the country. Each species requires a program of treatment especially adapted to its particular habits and life cycle. In spite of the great amount of money and time spent upon the problem of wireworm control for some years, the group remains a difficult one to check.

Biological control of wireworms is discussed by Sweetman (86, p.68, 169, 212, 215, 295, 339). Cultural practices include crop rotation, correct timing of planting, cultivation, plowing, draining, and the use of trap crops. Application of poisons to the seeds of crops before they are planted and the use of poisoned baits have helped to check the wireworm populations.

Most contact poisons are ineffective against these insects. O'Kane (66, p.108) asserts that no poisons applied to the soil will kill wireworms unless they are so strong that they will kill the plants also. Nevertheless many soil fumigants have been employed against the insects. The use of fumigants proves successful in some cases, but always entails so much expense that it is profitable only under intensive cultural conditions such as on golf courses or in greenhouses, nurseries,

and truck gardens.

Arsenicals, calcium cyanide, naphthalene, pyrethrum, carbon disulfide, chloropicrin, and dichloroethyl ether are among the poisons that have proved useful as soil fumigants. Discussions of wireworm control will be found not only in the references listed above but also in practically all entomology bulletins or textbooks.

Meloidae (blister beetles).

The Meloidae have a comparatively soft exoskeleton. Their common name is derived from the fact that many of them contain a substance (cantharidin) which produces blisters when applied to human skin. The heads of these beetles are abruptly constricted posteriorly into a short neck. The margins of the thorax are rounded, and the outline of the prothorax is either round or oval. The prothorax is usually narrower throughout and always narrower at its base than the elytra. The bodies of these beetles are rather slender and cylindrical.

The life histories of blister beetles are very distinctive, for they represent a complex type of development known as hypermetamorphosis. This means that the larvae assume different forms in successive stages.

More than 2000 species of blister beetles have been described. Over two hundred and fifty of these species occur in North America. Sweetman (86, p.204) says that the great

majority of the two hundred species of blister beetles described from the United States are found only in the western half of the country. The adults of fifteen or twenty species at times cause severe damage to a wide variety of grain and vegetable crops and garden flowers. Many of the larvae, on the other hand, are beneficial. They help reduce grasshopper populations by destroying the eggs.

Not only in the wide variety of their hosts plants do the *Meloidae* closely parallel the *Elateridae*. Here again the carrot is the only umbelliferous plant recorded as susceptible to attack, and the reports do not indicate that any particular species of blister beetle is responsible for the damage to carrots. A list of the *Meloidae* of greatest economic importance is here presented:

Epicauta cinerea (Forst.)(gray blister beetle)
Epicauta maculata (Say)(spotted blister beetle)
Epicauta marginata Fabricius (margined blister beetle)[4]
Epicauta pardalis Leconte (white spotted blister beetle)
Epicauta pennsylvanica (DeGeer) (black blister beetle)
Epicauta puncticollis (Mann)(punctured blister beetle)
Epicauta vittata Fabricius (striped blister beetle)[5]
Lytta cyanipennis (Leconte) (green blister beetle)
Lytta insperata (Horn)
Lytta nuttalli (Say) (Nuttall's blister beetle)
Lytta stygica (Leconte) (infernal blister beetle)
Macrobasis albida (Say)
Macrobasis fabricii (Leconte) (ash gray blister beetle)[6]
Macrobasis immaculata (Say)
Macrobasis longicollis (Leconte) (long blister beetle)

Blister beetles are found throughout the United States and

---

[4] Matheson (61, p.340) asserts that *E.marginata* Fabricius is probably a variety of *E.cinerea* (Forst.)

[5] Also known as *Epicauta lemniscata*.

[6] *Macrobasis unicolor* (Kirby) is also known as the ash gray blister beetle.

southern Canada. They feed upon the carrot and also upon:

alfalfa
barley
bean
beet
cabbage
clover
corn
cotton
cowpea
eggplant
melon
mustard
oats
onion
pea
potato
pumpkin
radish
soybean
spinach
sugar-beet
sweet potato
tomato
vetch

They damage weeds such as goldenrod and tarweed and also injure the following flowers:

anemone, Japanese
aster
calendula
carnation
chrysanthemum
clematis
dahlia
dianthus
gladiolus
meadow-rue
nicotiana
passion flower
pea-tree
phlox
verbena
zinnia

The active, restless adults feed ravenously on foliage and blossoms. They are gregarious and often travel in lines defoliating all of the plants in their path. Consequently, in many cases they do much damage before they are noticed. The feeding causes plants to look ragged and sometimes stunts their growth.

The majority of blister beetles produce only one generation each year. Metcalf and Flint (63, p.475) note that some of the species that feed on clover and alfalfa, such as the gray blister beetle, have two broods yearly. Matheson (61,p.339) points out that one of the larval stages may remain dormant for two or three years, thus lengthening the life cycle. Blister beetles hibernate as larvae.

Control. Very valuable plants may be covered with cheesecloth or mosquito netting. On a small scale, handpicking may

be sufficient, but gloves should be worn, for the beetles blister tender skin. It is often more desirable to knock or shake the insects from the plants into pans of kerosene or pans of water covered with a layer of kerosene.

A line of people armed with brush may drive the beetles before them into a windrow of straw which is subsequently burned. Many beetles may be destroyed by rolling hayfields with a heavy roller immediately after haying. Metcalf and Flint (63, p.392,332) advise going over infested clover and alfalfa fields with a hopperdozzer, a machine originally invented for collecting grasshoppers. Grasshoppers collected in this way may be dried and used for hog or chicken feed. Blister beetles cannot, of course, for they are poisonous if taken internally by animals.

Unfortunately blister beetles are rather resistant to poisons. In addition, they are so active that it is difficult to reach them with contact sprays. Doane (21, p.311) claims that arsenicals do not seem to be very effective. Other authors assert that arsenicals are repellent to the beetles, and Griswold (43, p.28) gives instructions for the preparation and application of arsenate of lead. Bordeaux mixture, either alone or combined with arsenicals, is said to give some measure of protection.

Barium or sodium fluosilicate and cryolite are reported to be more effective, but certain precautions described by Munro

and Riddle (65, p.18) and Gould (41, p.16) must be observed when using them. A contact insecticide, nicotine oleate, is recommended and described by Weigel and Middleton (97, p.4-5).

Chrysomelidae (leaf beetles).

The Chrysomelidae make up the largest family of beetles. They are small beetles, rarely exceeding one-half inch in length. They are characterized by having short antennae, plump bodies that are usually round or oval in outline, and elytra which cover all of the abdomen. The leaf beetles are diurnal.

Numerous tiny chrysomelids are classed together as flea beetles. They are so named because their enlarged hind femora enable them to hop away like fleas when disturbed. Many flea beetles are serious pests, and two species which are rather general feeders have been known to attack the Carrot Family. The larvae of these particular species are vermiform; that is, they are cylindrical, elongate, and lack locomotory appendages.

Epitrix cucumeris Harris.

Epitrix cucumeris, the potato, tomato, or cucumber flea beetle, has formerly been considered a member of the genus Haltica, and the genus Crepidodera. It is found throughout the

United States and in Canada. The potato flea beetle attacks celery and carrot as well as the following vegetables:

- bean
- beet
- cabbage
- clover
- corn
- cucumber
- eggplant
- lettuce
- muskmelon
- pepper
- potato
- pumpkin
- radish
- rhubarb
- spinach
- squash
- sweet potato
- tobacco
- tomato
- turnip
- watermelon

In addition it injures the following flowers:

- arbutus
- aster
- calendula
- dahlia
- evening primrose
- flowering tobacco
- holly
- honeysuckle
- hop
- lychnis
- mignonette
- petunia
- phlox
- sunflower
- violet

Epitrix cucumeris infests various trees and shrubs including apple, ash, elder, horse-chestnut, maple, raspberry, viburnum, and wonderberry. Several weeds are recorded as hosts of the potato flea beetle. They are:

- cherry
  - ground cherry
  - wild bird cherry
- dogbane
- horse-nettle
- Jimpson weed
- nightshade
- plantain
- St.John's wort
- sarsaparilla
- sorrel
- sumac

The adult flea beetle is less than two millimeters (eight-hundredths of an inch) in length. It is shining black with reddish or yellowish antennae. The legs are also reddish or yellowish except for the hind femora, which are brown. These adults hibernate in weeds or garden trash and in the spring

riddle the leaves of the host plants by eating many tiny holes through them. The holes facilitate the entrance of several agents of disease such as fungi. Badly infested leaves wither and die.

The females lay their eggs in cracks in the ground near the host plants. The eggs soon hatch into small white grubs which reach a length of about one-fifth of an inch. The larvae live in the soil and damage the roots of their host plants. Pupation takes place in the soil also. Two or three broods are produced annually, depending upon the locality. Lacroix (57, p.102) suggests the possibility of a single continuous brood.

Control. Control measures are directed against the adults, for the larvae usually cannot be reached. To be effective, treatments must be started early. Probably best results are obtained by dusting with cryolite or with barium fluosilicate as directed by Lacroix (57, p.103).

Flea beetles are repelled by spraying with Bordeaux mixture to which has been added lead or calcium arsenate or Paris green. Chupp and Leiby (10, p.82) explain the use of this mixture.

Munro and Riddle (65, p.48) claim that flea beetles are not satisfactorily destroyed by the use of arsenical sprays alone. Various calcium arsenate dusts have proved effective nevertheless. Chupp and Leiby (10, p.82) recommend the use

of a calcium arsenate and lime dust and Crosby *et al.* (17, p.69) advocate a calcium arsenate and copper oxide spray.

Chupp and Leiby (10, p.82) give directions also for the preparation of a rotenone spray and a rotenone and copper dust mixture, both of which they have found to give good results. Heavy applications of nicotine or pyrethrum dusts have been found successful by several workers. Where flea beetles are prevalent it is advisable to screen seedbeds and to dip the seedlings in a lead arsenate or Bordeaux and arsenate solution before transplanting them to the field.

Systena taeniata (Say).

Systena taeniata (Say) is also known as *S.ligata* Leconte, *S. blanda* Melsh., and *S. taeniata* var. *blanda* Say. Its common names are banded flea beetle and pale-striped flea beetle. The beetle ranges throughout the United States and is especially abundant in the west where several forms of it are known.

The banded flea beetle attacks almost all garden crops, including carrot, parsnip, and such other economically important plants as:

alfalfa
bean
beet
cabbage
clover
corn
cotton
eggplant
grasses
lettuce
melons
oats
peas
peanut
pear
potato
radish
strawberry
sugar-beet
tomato
turnip

It also injures wormwood and various flowers including aster, calendula, dahlia, hollyhock,and sunflower. The banded flea beetle, like the potato flea beetle, feeds on a variety of weeds. Its weedy hosts are cocklebur, Jamestown or Jimpson weed, lambsquarters, nightshade, pigweed, purslane, ragweed, sandbur, and sorrel (ordinary red or horse sorrel).

The adults are from three to four and one-half millimeters (about one-eighth of an inch) long. The various forms of the banded flea beetle differ markedly in color. They are shiny and range from pale yellow or reddish-yellow through shades of brown and black. Down the center of each elytron runs a pale longitudinal white or yellow stripe. Some specimens are cream-colored with three light brown stripes on their elytra. In most cases the eyes and underside of the beetle are black and the head is reddish-brown.

The damage done by the adults resembles the damage done by the adults of the potato flea beetle. In contrast, though,the eggs of the banded flea beetle are attached singly or in small groups to the lower parts of plants. The very slender white larvae are moderately hairy and about three millimeters long. They feed and pupate in the soil. O'Kane (66, p.157-158) says that one generation occurs annually while Essig (24, p.480) claims that at least two broods are produced each year.

Control. All of the methods advised for controlling the potato flea beetle may be used to combat the banded flea beetle.

Smith (83, p.221) asserts that dusting crop plants with air-slaked lime alone drives the beetles to nearby weedy hosts. Hutson (52, p.12-13, 29-30, 41) gives complete directions for the preparation and application of the various insecticides employed against the banded flea beetle. In addition, he stresses the value of destroying all garden rubbish and weeds. He describes a method of combating the insect on sugar-beets in Michigan, whereby the fields are rolled with a roller or "cultipacker" while the seedlings are small.

Curculionidae.

The Curculionidae is one of the families of snout beetles. Its members have the head drawn out anteriorly into a well-developed beak. The beak assists at oviposition by boring the hole in which the egg is subsequently laid and then by pushing the egg down into the hole. Near the center of the beak arises a pair of long slender antennae. The antennae are clubbed at the tip and are usually elbowed.

The grubs are white and soft and when at rest are typically found curled into the shape of a letter C. Their legs are represented merely by bristly elevations.

Two curculionids, if not controlled, can seriously hamper the production of umbelliferous crops.

Listroderes obliquus Gyllenhal.

The vegetable weevil, Listroderes obliquus Gyllenhal, has also been known as Listroderes costirostris Schoenherr. It was first described in 1834 by Gyllenhal from insects found in southern Brazil. By 1908 the pest had established itself on the southern and eastern coasts of Australia and has since been found in South Africa and the United States.

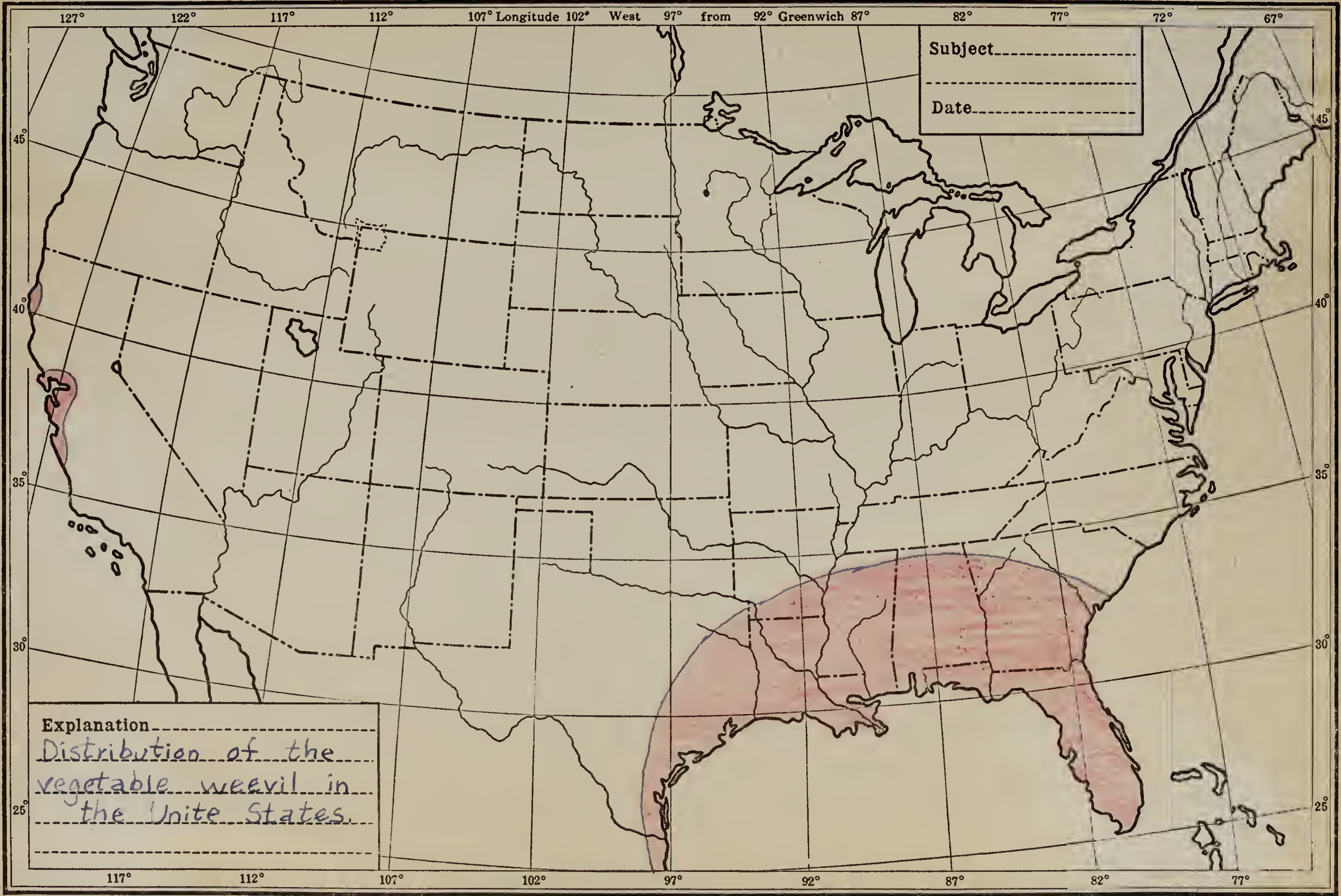
The vegetable weevil was first discovered in the United States in Mississippi in 1922, and has spread throughout the Gulf States. Shortly before 1926 it was introduced into San Francisco. It has been reported from eleven counties in this region. Just how it was introduced to the West Coast is not clear, but it was probably imported from Brazil or Australia.

Listroderes obliquus was originally known by the common name of tomato weevil. The fact that its list of host plants was later found to be quite varied has led to the adoption of the name of vegetable weevil. Its umbelliferous host plants are carrot, parsley, and parsnip. It also attacks cabbage, collard, lettuce, pear (foliage), potato, radish, spinach, Swiss chard, and turnip. The weevil can survive on the following weeds: chickweed, Malva spp.,milk thistle, mustard, pigweed, ragweed, Rumex spp., wild aster,and wild parsnip.

The adult weevil is about eight millimeters long (one-third of an inch) and four millimeters wide. It is a dull grayish-brown or buff color, which blends well with the soil. The

On the following page is a map which shows the distribution of the vegetable weevil in the United States,

McKinley's Geographical and Historical Outline Maps. No. 176b. The United States. (State boundaries.)



Subject

Date

Explanation Distribution of the vegetable weevil in the Unite States.

Copyright, McKinley Publishing Co., Philadelphia, Pa.

body and wings bear many scales and hairs. Each elytron is decorated with a pale gray oval or V-shaped group of scales. The beak or snout is stubby and thickset. It is equipped with a pair of elbowed and clubbed antennae. The prothorax becomes narrowed somewhat posteriorly.

The adult weevil remains in its pupal cell in the soil for several days after it has transformed. This allows time for its exoskeleton to become properly hardened. Emergence takes place in April or May, and the sociable insects gather in great numbers around young tomato and potato plants. It is not uncommon to find from twenty-five to forty weevils together in the soil around the base of a single plant. The pests feed at night and crawl under loose boards or other debris nearby during the day.

When the plants are young the vegetable weevil attacks them as does a cutworm, by chewing off the stems at ground level. When the plants are larger, the weevil climbs up into them to feed on the leaves or to cut the stem just below the growing tip. Tomato plants are usually so damaged that replanting is imperative.

Listroderes obliquus has well-developed wings but rarely flies. It has never been seen to fly in California.

Lovell (58, p.18) conducted experiments there to determine if it would be possible to control the weevils with light traps. He set up a large gasoline lantern in a badly infested carrot

field and kept it lighted from seven o'clock until nine o'clock in the evening. Frames surrounding the lantern were covered with paper on which tanglefoot had been smeared. The experiments were conducted during a number of evenings in May, when the young adults were emerging from the ground. On successive evenings paper of a variety of colors was used to cover the frames around the lantern. Large numbers of weevils were seen walking over the ground and feeding in an adjoining potato field, but none was perceived to fly. In the Gulf States and in Australia the weevil has been observed in flight, reportedly when the temperature was high. It relies chiefly upon its legs for locomotion, and at night when it is most active, may travel rapidly over the ground.

About the last of May adult weevils begin to go into estivation. For three months they lie hidden on the ground among weeds and crop refuse around cultivated areas.

In September they leave their over-summering quarters and seek fields of carrot, turnip,or spinach for oviposition. The vegetable weevil is parthenogénetic, so that any single adult female is capable of establishing its kind in a new area which provides suitable environmental conditions. At least in California males of the species are unknown.

Carrots and turnips are the plants preferred for egg-laying. The crowns of the plants are most often chosen for this purpose. The eggs are sometimes found in the soil nearby

and on the petioles of the leaves. The egg-laying period occupies half a year. Eggs are laid from the middle of September until the middle of March. In California a period of maximum oviposition occurs in October and November. Here, during the height of winter in December and January, egg-laying comes to a standstill, but picks up again in February.

Lovell (58, p.4-7) has made numerous and detailed studies of the oviposition of Listroderes obliquus. From him we learn that under laboratory conditions a single female may lay from one to over thirty eggs a day, and from three hundred to over fifteen hundred eggs a season.

His studies have shown that the insects prefer a damp place for egg-laying. When confined to Petri dishes containing only carrot foliage, they laid their eggs indiscriminately on the leaves or the glass floor. Sometimes two eggs protruded from the ovipositor before they were rubbed off by some projecting bit of foliage which the beetle ran over, or were forced off by other eggs.

When a piece of moist blotting paper was added to the dish, almost all of the eggs were laid upon it. Under this favorable condition the weevil followed a regular procedure for egg-laying. With the extended ovipositor she separated enough of the fibers of the blotter to produce a small aperture. This action was accompanied by a slight swaying movement. She then pushed an egg down into the cavity and packed the blotter fibers

firmly around it. Then a new position on the blotter was selected and the procedure was repeated.

At first the egg is white, spherical, and about one millimeter in diameter. It becomes progressively darker through shades of yellow and brown until just before hatching it is nearly black. At this time the tiny curled larva may be seen within the shell. The outline of the chitinized head may be distinguished, and it is said that even the movement of the mandibles can be observed. The larva frees itself from the egg by uncurling itself and breaking the shell. The length of time occupied by the egg stage has been found to vary between eleven and twenty-four days.

The newly hatched larvae are creamy white with light yellow heads. They are only about one-sixteenth of an inch long. As the larva matures it takes on a light green hue due to the passage of food through its alimentary tract. By maturity its heavily chitinized head has become dark brown, and its length has increased to one-half or five-eighths of an inch. These slender, strongly curved larvae lack jointed legs. They move by the alternate extension and contraction of ventral and lateral fleshy projections. A narrow prothoracic shield, cleft in the middle, is almost as dark as the head in color. After each of the four larval molts the head and prothoracic shield are white, but they become progressively darker both during each instar and from one instar to the next.

The entire larval life is spent feeding on the foliage of certain of the host plants, generally carrots and turnips. By November, from five to fifteen larvae will be found feeding on each infested plant and injury begins to be evident. The succulent young crown leaves are certain to be attacked.This resultsin stunted growth of the plant. Usually the larger veins of the older leaves are not eaten, but sometimes all of the plant that is above ground may be destroyed.

The presence of larvae in the foliage not only reduces the quantity and quality of the carrot or turnip root, but interferes with the marketing of these vegetables in other ways. Carrots must be bunched in order to be sold, and if the foliage has been eaten away, this is not possible. Furthermore, larvae found in the foliage by the average consumer will often cause a cessation of purchase. In addition, the infested tops, thrown out of doors, may result in the spread of the vegetable weevil.

After the fourth molt the larvae leave the host plants and burrow into the soil. There they construct earthen cells and pass a prepupal stage. A final molt initiates the true pupal stage. The pupae are about three-tenths of an inch long and have an average width of a little less than one-fifth of an inch. Lovell (58, p.9) describes them as possessing white heads, yellow legs and wing pads, and green abdomens. The short stout beaks are folded ventrally against the bodies and extend back as far as the coxae of the prothoracic legs. The pupae of the

vegetable weevil are more delicate even than are most pupae, and little force is required to destroy them.

Pupae will usually be found one or two inches below the surface of the ground, commencing in December and January. Under laboratory conditions the pupal stage is regularly completed in from fourteen to sixteen days. In the field, weather conditions greatly affect its duration.

Control. From the foregoing discussion it is obvious that careful and regular cultivation from December to April will rid a field of many of the vegetable weevils. A disk harrow is recommended for this purpose. The kill will be increased if this instrument is followed by a clod breaker.

Crop rotation when well planned will soon starve out the weevil. The larval hosts, such as carrots and turnips, must be avoided during the fall and early winter. These crops should never be followed immediately by the adult hosts sush as tomato and potato, especially in the spring. It is unsafe to plant any susceptible crops in succession in the same field or in adjoining fields.

Field sanitation faithfully practiced will reduce the destruction wrought by Listroderes obliquus. It is particularly important to rid the fields and neighboring areas of all weeds and crop refuse which may afford shelter to the estivating adults.

In order to get the full benefit of his efforts, the grower

should see to it that all weeds and debris are removed, down to the bare ground. The most effective time for field sanitation to be initiated is in April or May, before the adults begin to seek over-summering quarters.

The gregariousness of the adult vegetable weevil provides suitable conditions for the use of poison baits for their control. In late spring, as soon as damage in fields of tomatoes and potatoes is noticed, scatter the baits thinly over the surface of the soil between the rows of plants, especially near the borders of the field.

White and Doolittle (100, p.27) give the following formula and directions for vegetable weevil bait:

Sodium fluoride-- --------------------------½ pound
Fresh, finely chopped carrots or turnips---4 pounds
Dry wheat bran------------------------------7 "
Water to moisten--------------------3 or 4 quarts

The bran and fluoride are combined first and then are moistened with enough water so that each flake becomes wet. The chopped vegetables are added and the mixture allowed to stand for several hours before being applied.

Lovell (58, p.12) recommends a dried apple pulp coated with sodium fluosilicate. This is a patented product sold under the trade name of "Go West". It is scattered over the soil at the rate of seventy-five pounds an acre. Experiments using dried apricots and lemon juice have turned out favorably. In any case, fruits and fruit juices are known to give better results than molasses.

The most reliable control for Listroderes obliquus is treatment with insecticides, particularly those in dust form. Insecticides should be used whenever the seriousness of the damage and the value of the crop demand immediate action. If the foliage is to be eaten neither by humans nor by domesticated animals, it may be dusted with undiluted calcium arsenate. Instead, a spray may be made by combining one ounce (five level tablespoonfuls) of calcium arsenate, three ounces of hydrated lime, and one gallon of water.

Some authorities believe that there is danger to humans from the use of arsenicals on carrots or turnips. On the market at the present time are several fluorine compounds which are far less toxic to man and provide efficient and inexpensive substitutes for arsenicals. Sodium fluosilicate can be safely used as a dust on the host plants attacked by the larva or by the adult, with one exception. It may seriously burn potato foliage, especially in the San Francisco Bay region. Barium fluosilicate may be used safely on potato, as well as on the other hosts of the vegetable weevil. Its disadvantages are a slightly greater cost and a somewhat slower action.

If fluosilicates are applied when larval injury is first noticed, generally about the first of November, they will not only kill the newly hatched larvae , but also some of the adults which are still laying eggs. Fluosilicates are commonly diluted by twenty or thirty percent of a carrier such as diatomaceous earth. For protection of crops grown in rows, such as

carrots and turnips, the dust is best applied by a rotary duster similar to the one to be described under the control of the celery leaf-tier. The amount used varies from fifteen to forty pounds an acre depending upon the age of the plants and the corresponding denseness of the foliage.

If the plants attacked are very young, two applications will probably be found necessary. In most other cases, one application will give the desired control.

The injury done to potatoes and tomatoes in the spring by the feeding of the adults occurs soon after these crops have been set out in the field. The plants are small and far apart. Fluosilicate dusts should be applied at this time with some form of hand duster. Not only the foliage but also the ground around the base of the plant must be reached by the dust. Ten to twelve pounds of dust an acre will be found to give sufficient protection to these young plants.

A cryolite[7] dust or spray is recommended by White and Doolittle (100, p.23) for the control of the vegetable weevil. The dust is prepared by mixing two pounds of cryolite with one pound of talc. The spray is prepared by mixing an ounce (eight level teaspoonfuls) of cryolite with one gallon of water. Neither lime nor Bordeaux mixture must ever be used with cryolite.

Lovell (58, p.15) reports experiments in which numerous chemicals were employed as attrahents. There follows a list

---

[7] Cryolite is sodium aluminim fluoride.

of the chemicals tested in his experiments:

- Acetate, ammonium
  - , amyl
  - , bornyl
  - , butyl
  - , calcium
  - , ethyl
  - , isopropyl
  - , terpenyl
- Acetoacetate, ethyl
- Alcohol, benzyl
  - , butyl
  - , carvocral
  - , cinnamyl
- Aldehyde, cinnamic
- Anethole
- Anisaldehyde
- Anisic acid
- Anisole
- Anisole, 3-nitro,4-acetylamino
  - 5-nitro,2 amino
- Anthole
- Anthracene
- Anthranitate, methyl
- Asparic acid
- Benzaldehyde
- Benzoate, benzyl
  - , calcium
  - , ethyl
  - , methyl
- Borneol
- Butyrate, cinnamyl
  - , ethyl
- Butyric acid
- Capric acid
- Cinnamaldehyde
- Cinnamate, benzyl
  - , butyl
  - , linalool
- Cinnamate, methyl
  - , phenyl ethyl
  - , sodium
  - , terpineol
- Cinnamic acid
- Cinnamon, ground
- Citrol
- Citronellal
- Cumene
- Cymene
- Ether, petroleum
- Eugenol
- Formic acid
- Geraniol
- Hexane
- Hippuric acid
- Hydrate, terpin
- Hydrocinnamic acid
- Isovaleric acid
- Ketone, methyl ethyl
- Lactic acid
- Limonene
- Malic acid
- Menthol
- Nitrobenzaldehyde
- Nitrobenzene
- Nitrocinnamic acid
- Oxalic acid
- Propionate, cinnamyl
- Propionic acid
- Safrol
- Salicylaldehyde
- Salicylate, amyl
  - , ethyl
  - , phenyl
  - , sodium
- Succinic acid
- Terpineol
- Thymol

Lovell (58, p.15) describes the procedure thus:

> Paper cups were filled with wet bran and the various chemicals were sprinkled on the top. Some of the cups were sunk into the ground with screen guards about them to hold the weevils and some were placed on the surface in wire cages. Wide-mouthed jars were sunk into the soil with the mouths level with the surface and the several chemicals were placed at the bottoms of the jars on cotton pads; also a combination of the sunken jars and paper cups was used, that is, the jars were sunk into the ground, the paper cups were attached over the mouths of the jars by wires, and the chemicals were put onto the bran in the cups.

The compounds containing anise and cinnamon proved only slightly and irregularly attractive to the weevils. The experimenters concluded that not one of the chemicals tested would be of any commercial value for this purpose.

Lovell (58, p.16-18) also reports the results of experiments with paradichlorobenzene and carbon disulfide emulsion as soil fumigants. Paradichlorobenzene was used in carrot fields that had been attacked by the vegetable weevil. A shallow furrow was made between the double rows and the chemical was poured in at the rate of one ounce for four feet of row. The furrow was then filled in. After five days the soil was examined. All larvae and pupae encountered were found to be alive. The carrots appeared to be uninjured by the chemical.

They used a fifty percent carbon disulfide emulsion prepared as directed by the Japanese Beetle Laboratory in Morristown, New Jersey. It was used at strengths of fifteen cc., thirty cc., forty-five cc., and sixty cc. to one gallon of

water. These varying concentrations were applied at the rate of one quart of mixture to one square foot of row. The experiment was first carried out when the temperature of the ground was eight degrees centigrade. It was repeated once when the ground temperature was fourteen degrees centigrade, and again when the ground temperature was eighteen degrees centigrade. Different areas of the treated soil were examined at times varying from one to five days after application. The highest kill, only nine and two-thirds percent, was given by the experiment conducted at soil temperature of fourteen degrees centigrade.

The workers have advanced two reasons which may account for the failure of the soil fumigation experiments. The first is that pupation occurs in midwinter. At this time the ground is so cold and wet that not enough gas may be set free to suffocate the insects. The other reason is that the gas, which is much heavier than air, may immediately settle below the top two inches of the soil, in which the pupae are found. Whatever the reasons, there seems to be no value in the use of soil fumigants against Listroderes obliquus.

Listronotus latiusculus (Boheman).

Listronotus latiusculus (Boheman) is commonly called the carrot weevil. It was described by Chittenden (6, p.14-19) in 1909 under the name of the parsley stalk weevil.

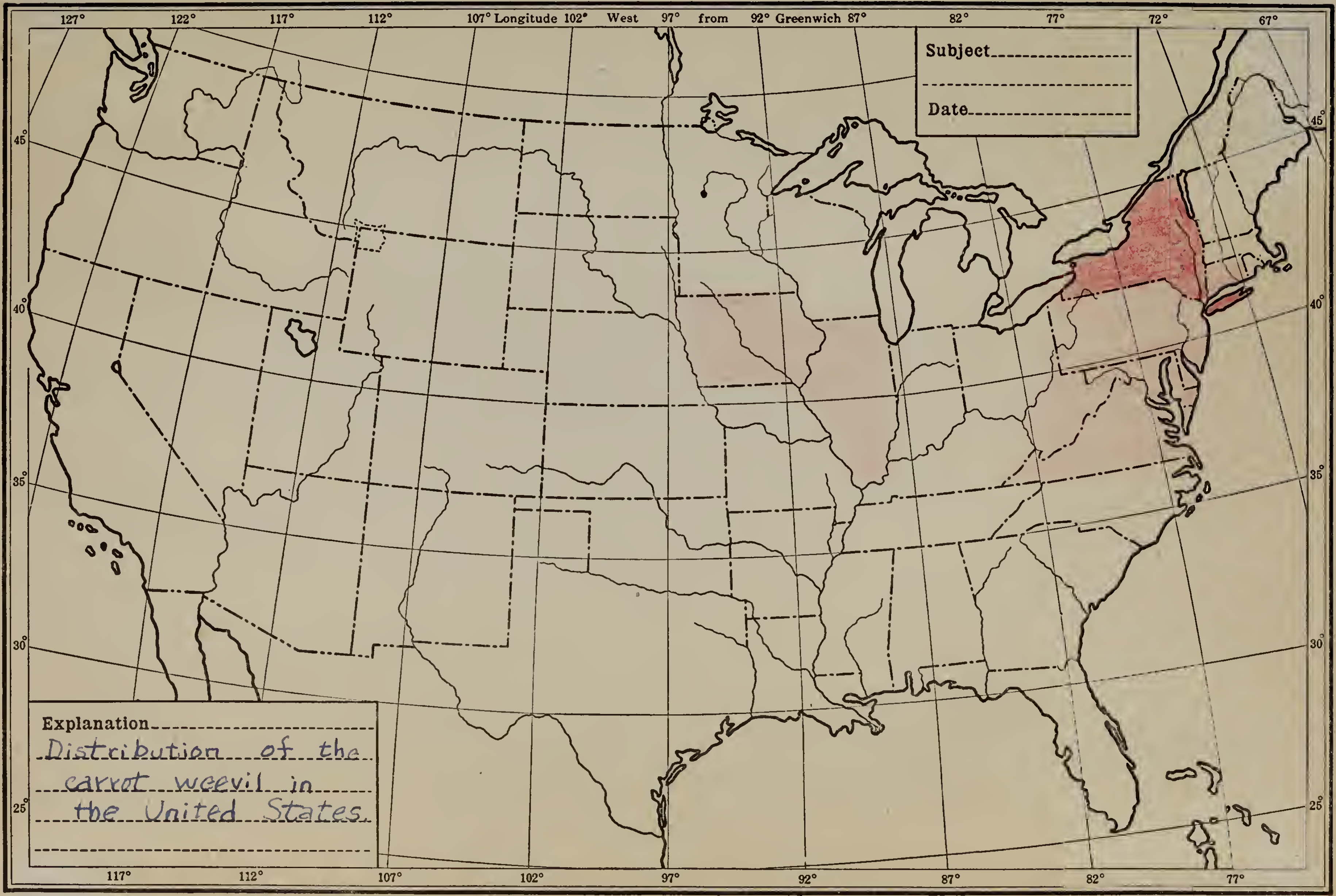
The carrot weevil is one of the more recent pests to invade our gardens. The first evidence of damage caused by this insect was on parsley at Four Mile Run, Virginia, in 1900. The pest has spread slowly. It now ranges from Connecticut to Virginia and seems to be particularly prevalent in New York. It has been found as far west as Illinois and Iowa.

The greatest amount of injury by the carrot weevil occurs on early crops of carrots. It has also been found attacking celery, parsley (especially curled-leaved parsley), parsnip, dill, and hymicha. Its most common wild host, at least in the New York area, is wild carrot. If cultivated crops are not available, it will feed on plantain, dock, and arrowhead.

The adult weevils, which hibernate in the immediate vicinity of an infested field, become active in May (earlier, of course,in the southern part of their range). Their dark brown bodies are covered with tiny golden or copper-colored scales. The length of the weevil varies from six to seven and one-half millimeters (about one-quarter of an inch). This measurement does not include the rostrum or snout, which from its tip to the eyes is almost as long as the thorax.

On the following page is a map which shows the distribution of the carrot weevil in the United States. Intensity of coloration represents intensity of carrot weevil population.

McKinley's Geographical and Historical Outline Maps. No. 176b. The United States. (State boundaries.)



Explanation

Distribution of the carrot weevil in the United States.

Copyright, McKinley Publishing Co., Philadelphia, Pa.

Listronotus latiusculus at first glance resembles several other species of curculionids. Particularly noticeable is its similarity to the clover-leaf weevil and related species (genus Phytonomus).[8] The carrot weevil may be distinguished from members of this genus by the varying proportions of its ventral segments. The first, second, and fifth segments are long; the third and fourth are very short. Its legs are slimmer and its tibiae are bent inward at their tips in abruptly sharp points.

The carrot weevil flies, but apparently does not travel far. The feeding of the adults causes little damage. Soon after they appear, the females begin to lay their eggs, usually in stems. Crosby et al.(17, p.78) affirm that the beetle places three or four eggs in a cavity which she has hollowed out in a leafstalk. The aperture is then sealed with a blackish substance. Chittenden (6, p. 17) claims that the usual number of eggs inserted is two, although a third is often found, and sometimes only one.[9] In a large stalk three or four egg cavities are commonly found distributed from just below the top nearly to the base.

The egg is smooth, oval, and from seven-tenths to three-fourths of a millimeter in length (three-hundredths of an inch). It is from two-thirds to three-fourths as wide as it is long, and is not noticeably flattened.

---

[8] The genera Listronotus and Phytonomus are very closely related.

[9] Most curculionids lay only a single egg in each cavity or slit.

The eggs hatch in about ten days into fat, milk-white, footless grubs. The grubs are less curved than most curculionid larvae, and a good deal more flattened. They are relatively active, for their modified shape enables them to crawl easily. They are slightly longer than the adults. The larva's pale, reddish-brown head is comparatively small and bears darker brown mouthparts..

Upon hatching in carrots, the grubs begin feeding within the stalk, at the same time boring downward toward the root. The journey to the root is generally accomplished without the larva's coming to the surface at all. However, those that hatch at some distance from the ground bore out of the stem and tumble to the ground where they soon bore into the carrot itself. In the case of plants that were killed by too many egg-laying punctures when they were young and tender, the larvae desert the stem in the same way. These small plants which have a stem less than a quarter of an inch in diameter are soon killed. Damage to plants having stems attacked when one-half to three-quarters of an inch in diameter is not so evident.

It is common for several larvae to attack a single carrot. The feeding is generally limited to the upper and outer parts of the root, causing very irregular light reddish-brown grooves over the surface. Within, the crooked burrows frequently run together, the large areas where several burrows intersect often breaking through to the surface. Individual burrows in large roots average one inch in length and one-quarter inch in

diameter. The decay of the carrot is hastened by the large amounts of soil washed by rains into the exposed excavations. Badly injured carrots are unmarketable, and on Long Island the damage to early carrots may amount to as much as seventy-five percent of the crop.

In celery the damage may be largely in the stems. In parsley, attacks on the roots result in the production of an unhealthy yellowish hue in the leaves, which greatly lowers their market value. Continued injury causes the leaves to wilt and dry out. Similar root injury to hymicha may at times render it worthless.

The larvae become full grown in about two weeks. They burrow out of the root and construct earthen cells in the soil only an inch or so away. Here they transform to pupae. The creamy white pupa is most unusual. It is covered with numerous short stiff setae which aid in locomotion. It is quite active and able to travel a considerable distance. The length of the pupal stage varies from six to twelve days.

In July, the adults of the second generation emerge from their earthen cells and in turn produce a second brood of larvae. These larvae injure carrots during their feeding period in August. In Virginia, larvae have been observed hatching as late as the fourth of September. In some localities at least, a partial third generation may develop, but its injury is so slight as to be unimportant economically.

As we have stated, the beetles fly very little, although they possess wings. Hence their spread from field to field takes place so slowly that proper rotation of crops alone solves the problem. It is possible to grow carrots safely in the midst of weevil infested districts by choosing for them fields not recently planted to any of the umbelliferous hosts mentioned. The presence of wild hosts in or around the fields must likewise be avoided of course.

Sometimes it is not practical to sidestep susceptible crops or to practice crop rotation at all. For example, land suited to the production of celery is not abundant and must be planted to celery without interruption. Consequently, insecticidal measures have been sought for control of the carrot weevil. Experiments with arsenicals, used both as sprays and as baits, have proved promising but have not as yet proceeded to the point where definite directions can be given.

Chittenden (6, p.18) stated that although he had never experimented with the control of this insect, he had no doubt that it could be reached by carbon disulfide or kerosene emulsion applied to the soil about the roots as for root maggots.

Scarabaeidae (lamellicorn beetles or cockchafers).

The beetles usually have stout and rather short rounded bodies. The elytra seldom cover the entire abdomen. The

antennae of the Scarabaeidae have from three to seven of the terminal segments flattened and broadened on one side into thin plates. The beetles can move the lamellae which compose this club, but they generally hold them close together.

The grubs in most cases are soft and fat, with well developed thoracic legs. The abdomen is somewhat swollen posteriorly, and the whole body is more or less curved.

It is estimated that there are over 16,000 species in this very large and important family. Many of the 1200 species found in North America are pests. The varied habits of the Scarabaeidae make it possible to divide them into two main groups. The first group, scavengers, is beneficial although of no great economic importance. Both as larvae and adults its members feed on decaying vegetable matter. The second group, leaf chafers, contains many destructive forms. The adults feed on the foliage, flowers, or fruit of plants, while the larvae live in the ground and feed on decaying wood or more often on the roots of crops or grasses.

The members of the genus Phyllophaga, taken collectively, and Autoserica castanea (Arrow) deserve brief mention. They are very general feeders which have been known to injure carrots. Another species, Ligyrus gibbosus (DeGeer) while also a rather general feeder, shows a marked preference for the Umbelliferae.

Autoserica castanea (Arrow).[10]

The Asiatic garden beetle was first reported here in 1921, in New Jersey. It is now commonest in New York and New Jersey, but is also found in Connecticut, Pennsylvania, Delaware, Maryland, Virginia, District of Columbia, and South Carolina. Hallock and Hawley (44, p. 10) have published a list of eighty-two host plants of the Asiatic garden beetle. Some of the commonest hosts[11] are:

Vegetables:

bean
beet
broccoli
cabbage
carrot
eggplant
parsnip
pepper
rhubarb
spinach
swiss chard
turnip

Trees:

cherry
devils-walkingstick
locust
peach
plum
sumac
tree-of-heaven
viburnum
willow

Flowers:

ageratum
aster
chrysanthemum
cosmos
dahlia
delphinium
flame-ray gerbera
foxglove
gaillardia
golden glow
heliotrope
hemp
lemon verbena
morning glory
petunia
phlox
rose
salvia
Shasta daisy
strawflower
sunflower
sweet mock orange
zinnia

Weeds: burdock, goldenrod, ragweed, and plantain.

The adult beetles are dull chestnut or cinnamon brown in color and measure from three-eighths to one-half inch long.

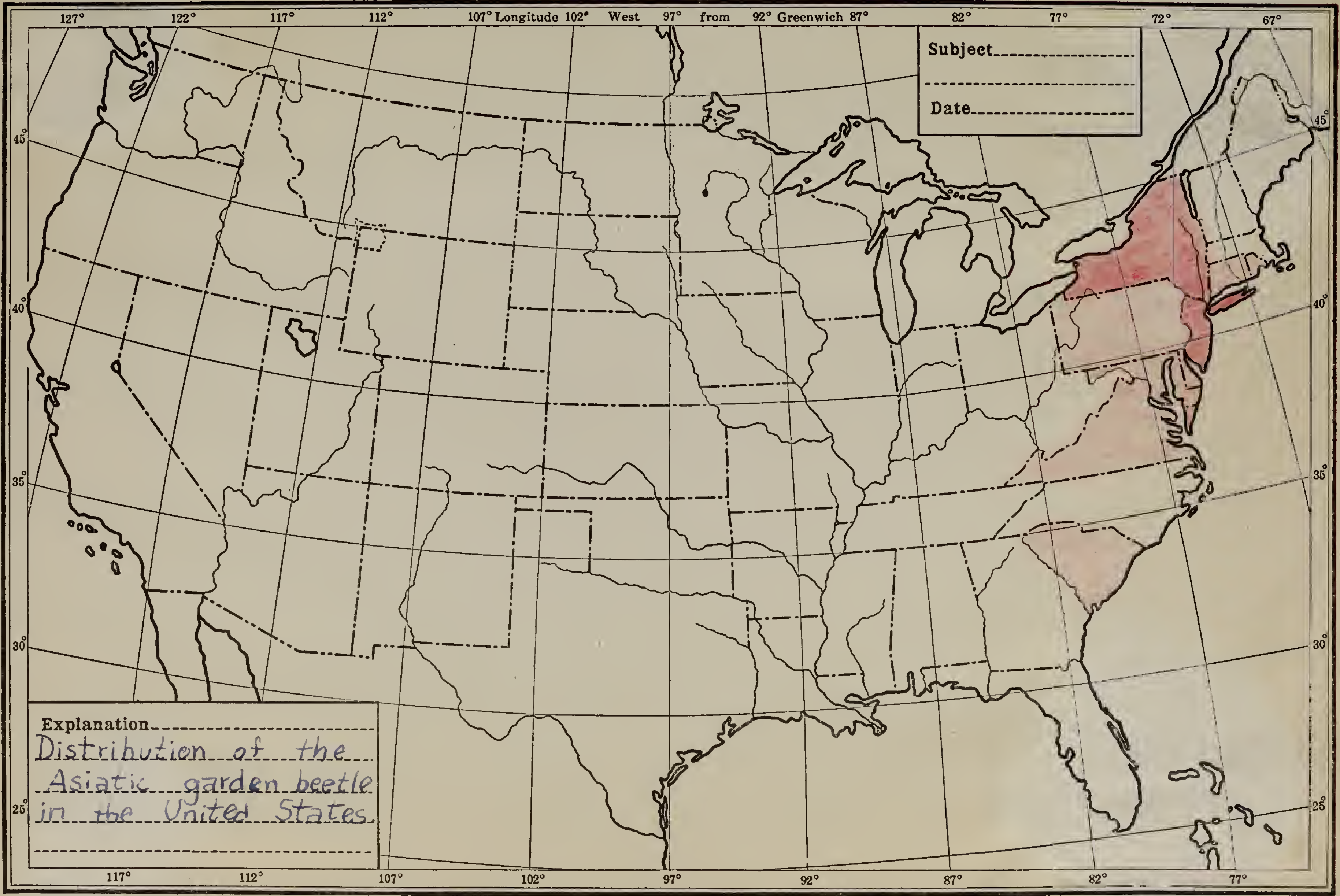
---

[10] Sometimes placed in the genus *Aserica*.

[11] Not all of these hosts are included in Hallock and Hawley's list.

On the following page is a map which illustrates the distribution of the Asiatic garden beetle in the United States. Intensity of coloration indicates intensity of Asiatic garden beetle population.

McKinley's Geographical and Historical Outline Maps. No. 176b. The United States. (State boundaries.)



Subject

Date

Explanation Distribution of the Asiatic garden beetle in the United States.

Copyright, McKinley Publishing Co., Philadelphia, Pa.

The eggs, which are laid in the soil, hatch into grubs which cause extensive injury by feeding upon the roots of plants. These larvae attain a length of approximately one-half inch and pass the winter from nine to fifteen inches below ground level. The following year they resume feeding for a couple of months and then pupate in the soil. A year is required to complete the life cycle.

Control. Many larvae are destroyed by prolonged dry spells. On a small scale damage by the adults may be minimized by handpicking and by screening choice plants. Traps baited with geraniol collect a small percentage of the adults. Foliage is commonly sprayed with arsenicals to kill the adults. Fernald and Shepard (27, p.181) give directions for the preparation and use of lead arsenate. Oleate-coated arsenate of lead, as used to control the Japanese beetles, is recommended by Herrick (49, p.372, 147-149).

The application of lead arsenate to the soil has proved effective against the larvae. Hallock and Hawley (44) describe this and other methods of control in their United States Department of Agriculture Bulletin, Life History and Control of the Asiatic Garden Beetle.

Ligyrus gibbosus (DeGeer).

Ligyrus gibbosus (DeGeer) is popularly called the carrot beetle or the muck beetle. It is widely distributed in the

United States, but does not occur in the most northern states.

The Umbelliferae attacked by Ligyrus gibbosus are carrot, celery, and parsnip. Other vegetables and some grains damaged are barley, beet, cabbage, corn, cotton, grasses, oats, potato, sugar-beet, sweet potato, and wheat. The carrot beetle's host plants include also trees -- elm and oak, and garden plants -- dahlia and sunflower. The weeds most commonly fed upon by this species are amaranthus, pigweed, ragweed, and wild sunflower. It is said that the carrot beetle is cannibalistic when hard pressed.

Ligyrus gibbosus is shining reddish-brown in color, although some individuals are found which are distinctly black above and reddish underneath. The beetle is from one-half to three-fifths of an inch long and a little over half as wide. It is heavily built and thick-set, with stout, spiny legs. A transverse ridge is present, dorsally, on the head.

Certain features are used to distinguish Ligyrus gibbosus from closely related species. One of these is the rather long hair on its ventral surface. Another, said to be the most reliable one, is the presence of a median impression near the anterior margin of the pronotum. Just in front of this impression is a small blunt projection. Transverse rugulae are absent in this species.

When carrot beetles are handled they generally produce a low but audible sound. They produce this noise by rubbing their legs over the finely wrinkled inner surfaces of their elytra.

These adult beetles hibernate in the soil, sometimes as far as four feet below the surface. They appear usually in late April and cause damage by their feeding until sometime in August. They eat large holes into or through the bases of cornstalks or celery stalks. They injure carrots and parsnips by excavating in the roots.

During the first part of their feeding period, in early spring, the females lay eggs in the soil at night. They lay the eggs near the host plants in rich humus if possible. The smooth, pure white, nearly spherical eggs increase greatly in size before hatching. Just before hatching their size is about one and five-tenths of a millimeter by one and eight-tenths of a millimeter. The incubation time varies from one to three weeks.

The larvae of the carrot beetle resemble common white grubs, being fat, curved, and white, sometimes with a bluish hue. The spiracles are brown, and the head, when fully chitinized, varies in color from reddish to brown. The head is usually smooth, but may bear very fine, light wrinkles. At maturity the larva reaches a length of one and one-quarter inches (thirty-one millimeters.)

The larvae may be largely scavengers, feeding in soils

that have an increased humus content owing to the presence of decaying vegetation in it. Unfortunately, the larvae as well as the adults cause damage to crops. The larvae are quite general feeders on the roots of grains, grasses, and weeds. A dozen or more grubs may be found around the roots of a single plant.

Pupation usually occurs in the month of August. The pupa greatly resembles that of a close relative, *Ligyrus rugiceps*, but can be distinguished from it by certain anatomical features. The mandibles of *L.gibbosus* are smaller and slenderer than those of *L. rugiceps*. Their apex, which lies against the almost straight sides of the labrum, is blunt rather than angular. The maxillary palpi are shorter and more rounded at the tips than are those of *L. rugiceps*. In addition, the postcoxal process of the prosternum is less erect and more sharply pointed than in *L. rugiceps*. A final characteristic which identifies the pupa of the carrot beetle is the presence of pronounced two-ribbed wing pads.

The transformation to the adult takes place in late summer. The freshly emerged beetles feed for a while before seeking winter quarters. There is but one generation a year.

Control. Peairs (70, p. 265) states that parasites greatly aid in reducing the numbers of the carrot beetle. He speaks of having had recent reports from Delaware that eighty-five percent of these beetles had been found killed by various parasites there.

Although Metcalf and Flint (63, p. 515) claim that no successful control methods for the carrot beetle are known, it is certainly true that the numbers of this pest can be partly kept in check by cultural practices.

Numerous writers have advised prevention of the accumulation of decaying crop remnants and weeds in the top layers of soil. The lack of such organic material in the soil would seem to me to cause the versatile larvae to attack the crop roots all the sooner, particularly if the crop were a grass or a grain. Weedy hosts of the carrot weevil, of course, such as wild carrot, dock, plantain, and arrow head, must be eradicated from cultivated areas and from the fields adjoining them.

Probably the most advisable cultural method is deep fall plowing. It must be remembered, of course, that the hibernating adults may be as far as four feet below the surface of the ground. Late summer plowing, if possible, would undoubtedly be still more effective, for it would tend to destroy the more vulnerable pupae. Plowing kills some of the insects directly by mechanical injury. Many others are turned up and subsequently eaten by insectivorous birds and rodents or killed by the alternate freezing and thawing of winter.

The grubs may be starved out by leaving badly infested fields plowed and unplanted for a year. Should the carrot weevil assume greater and more widespread importance, insecticidal measures will undoubtedly be developed.

Phyllophaga.[12]

The adult members of this genus are commonly called May beetles, June beetles, June bugs, daw-bugs, or dor-bugs. The larvae are the well-known white grubs.

Metcalf and Flint (63, p.307) have described the distribution of white grubs as world-wide. They are found throughout the United States and Canada, although they are not as numerous west of the Rocky Mountains. Neither are they often seriously abundant in New England. Munro and Riddle (65, p.60) report that they are of minor importance in North Dakota.

White grub populations are most abundant in the Mississippi Valley and in the Great Lakes region. The greatest amount of research on the genus has been done by entomologists of the Michigan and Illinois agricultural experiment stations. Several of their bulletins are included in the following list of references found in the bibliography of this paper: (30), (32), (33), (45), (46), (59), and (74).

An exhaustive list of host plants of *Phyllophaga* is not attempted. Some of the plants attacked by the adults and larvae are:

Crop Plants:

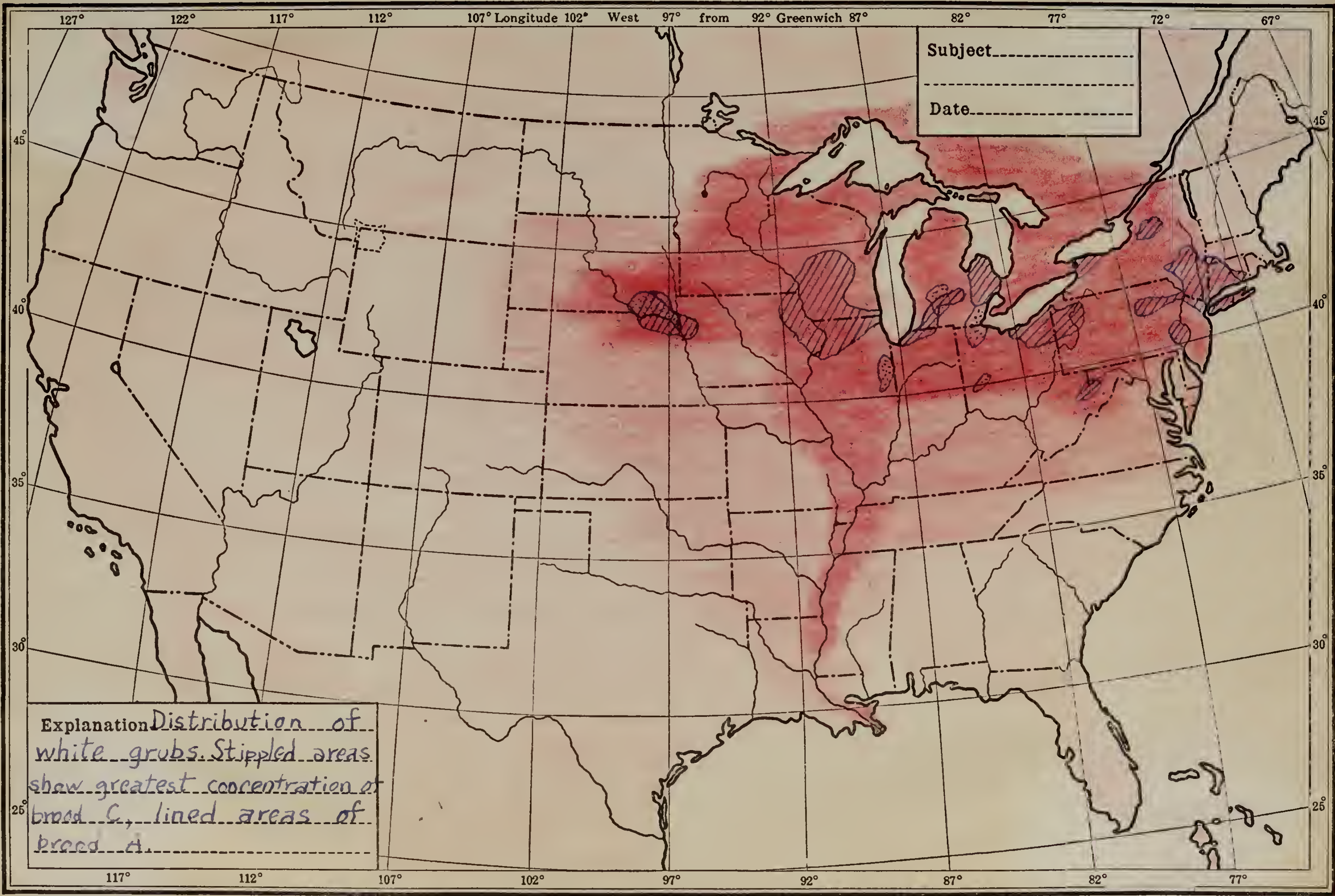
- barley
- bean
- beet
- blackberry
- carrot
- corn
- cotton
- gooseberry
- oats
- potato
- rye
- strawberry
- timothy
- wheat

---

[12] The members of this genus were formerly placed in the genus *Lachnosterna* and in the genus *Cyclocephala.*

On the following page is a map showing the distribution of white grubs. Intensity of coloration indicates intensity of white grub population. Stippled areas show the greatest concentration of brood C, lined areas of brood A.

McKinley's Geographical and Historical Outline Maps. No. 176b. The United States. (State boundaries.)



Subject

Date

Explanation Distribution of white grubs. Stippled areas show greatest concentration of brood C., lined areas of brood A.

Copyright, McKinley Publishing Co., Philadelphia, Pa.

Trees:
- apple
- ash
- birch
- box-elder
- butternut
- dogwood
- elm
- hackberry
- hazel
- hickory
- larch
- linden
- locust
- maple
- oak
- pine
- poplar
- tulip tree
- walnut
- willow

Flowers:
- aster
- chrysanthemum
- cyclamen
- dahlia
- geranium
- gladiolus
- hyacinth
- iris
- larkspur
- pansy
- peppermint
- phlox
- primrose
- privet
- rose
- snapdragon
- spearmint
- strawflower
- violet

Weedy hosts of *Phyllophaga* include bluegrass, dandelion, and shepherd's purse. The beetles are said to dislike alfalfa, buckwheat, soybeans, and sweet clover.

"May beetles are robust and thickset. They are rather glossy, and vary in color from pale gray, reddish, or yellowish to nearly black. They range from slightly under one-half inch to one and one-half inches in length. They feed on foliage at night and sometimes defoliate large stands of timber.

The larvae fit perfectly the general description given under the *Scarabaeidae*. They have rather large brown heads and measure from one-half inch to over one-inch in length. They feed upon decaying vegetation and roots. Small roots are eaten off and the surfaces of large roots are excavated. White grubs require from one to four years to complete their life cycles, depending upon the species and upon the latitude.

Control. Both dipterous and hymenopterous parasites destroy white grubs. Various mammals, birds, amphibians, and insects prey upon them They are also subject to mycoses and to bacterial and virus diseases. Some of the enemies of white grubs are described by Forbes (33, p.468-475) and by Luginbill (59, p.9, 12-13).

Such cultural practices as planned crop rotation, proper timing of planting, plowing, and clean cultivation must be observed in grub-infested areas. The use of trap lanterns, screening, and poisoned baits is widely employed. Arsenate of lead is recommended both as a soil poison and a foliage spray.

Soil fumigation with carbon disulfide is claimed effective by Metcalf and Flint (63, p.723), Herrick (49, p.219), Weigel and Middleton (97, p.49), and The Garden Encyclopedia (81, p.123,690). Weigel and Middleton (97, p.49) give directions for the preparation and use of carbon disulphide as a soil fumigant. On the other hand, O'Kane (66, p.109) states that there is no chemical that will kill white grubs when applied to the soil. Peairs (70, p.99) asserts that soil fumigation is no longer recommended.

Soil sterilization with steam gives control of white grubs in greenhouse soils. Instructions for the use of this method are given by Metcalf and Flint (63, p.723). Detailed information concerning the control of white grubs is presented in the bulletins cited near the beginning of the discussion of Phyllophaga.

CHAPTER III -- LEPIDOPTERA.

The adult Lepidoptera are the moths and butterflies. They usually have two pairs of large membranous wings more or less covered with overlapping scales. Their mouthparts are fitted for sucking. Since the adults have no ovipositor, the eggs are always laid on a surface or in a crack or other opening that is large enough to admit the abdomen of the female. The larvae, which are called caterpillars, are rather worm-like in form. They have chewing mouthparts. Caterpillars vary from naked to woolly in appearance, depending upon the number of hairs, bristles, and spines they bear. In the moth families the full-grown caterpillars may spin a cocoon about themselves and transform to the pupal stage within. The outlines of the adult body and its appendages show through the pupal skin. In the butterfly families, the pupa is formed by attaching the posterior end of the body to a support and spinning a silken loop around the middle to hold it up. Such a specialized pupa is called a chrysalis.

Over 100,100 species of Lepidoptera are known. About seventy families are represented in North America. At least fourteen species of Lepidoptera have been recorded as attacking Umbelliferae, but only five of these species show any specificity for the Carrot Family.

Tortricidae.

The Tortricidae comprise a family of comparatively small moths. The members of this group have rather rough heads and fairly broad forewings. The elongated, slightly hairy larvae vary greatly in habit. The pupae bear two dorsal rows of spines on most of their abdominal segments.

This very large family is represented in North America by probably over one thousand species. Among the serious agricultural pests which belong to this group is a species which according to one report includes celery among its long list of host plants.

Archips rosaceana (Harris).[1]

Archips rosaceana is commonly called the oblique-banded leaf-roller. It is widely distributed throughout northern United States, and Herrick (49, p. 382) says that it ranges from Maine to California. Its northeastern limits extend at least into Nova Scotia. It is reported from North Dakota also.

This leaf-roller may damage celery as well as bean, clover, cotton, and horseradish. It is primarily a pest of trees and shrubs, and causes trouble in orchards by feeding upon apple, apricot, cherry, peach, pear, plum, and prune. Other trees and shrubs listed as hosts are:

---

[1] Often placed in genus Cacoecia, sometimes spelled Cacaecia.

ash
basswood
beech
birch
box elder
dogwood
elm
hawthorn
hazlenut
horse chestnut
lilac
maple
oak
poplar
spirea
sumac
witch hazel
yellow birch

In addition, the oblique-banded leaf-roller feeds upon the following berries:

blackberry
currant
loganberry
gooseberry
raspberry
strawberry

In flower gardens and greenhouses it attacks:

aster
carnation
geranium
hawthorn
rose
sunflower
verbena

Its weedy hosts are burdock, knotweed, ragweed, smartweed, and thistle.

The adults are smooth reddish brown or brownish moths. The light cinnamon brown forewings are crossed by many fine irregular dark brown lines and by a wide dark oblique band across the middle. The hindwings are ochre yellow and the wingspread is approximately one inch.

The greenish eggs are laid in overlapping masses on the branches of the host plants. They hatch into light yellowish green or reddish caterpillars which when full grown measure about three-quarters of an inch long. At first the larvae feed upon the soft tissue of young leaves. Soon they roll up one or several leaves, tie them with silk, and feed within upon the developing flower buds. They pupate within the rolled leaves also.

Herrick (49, p. 382) claims that there is some uncertainty as to how the oblique-banded leaf-roller passes the winter, and as to how many broods occur each year. In North Dakota and at least some of the other western states, the winter is passed in the egg stage. In Nova Scotia, on the other hand, partly grown larvae hibernate in small nests at the ends of twigs or fruit spurs. Weigel and Middleton (97, p. 17) of the United States Department of Agriculture state that there are apparently two broods annually.

When infestation of the oblique-banded leaf-roller is light, it is practicable to handpick the larvae and destroy the adults by the use of trap lanterns. More serious infestations will require the use of Paris green or arsenate of lead. Weigel and Sasscer (98, p. 64) recommend a dust of one part arsenate of lead to nine parts superfine sulfur. Fumigation with nicotine or cyanide will destroy the adults. Neither contact sprays nor fumigants usually reach larvae feeding within buds. Infested buds, therefore, should be cut and burned. Miscible oil or crude oil emulsion sprays applied during the winter will kill the eggs. For further information on the biology and control of the oblique-banded leaf-roller see McDaniel (62, p. 73-75).

Pyralididae.

Most of the moths included in this vast family are small, although some are medium-sized. They are slender and delicate in appearance, with proportionately long legs. The larvae are slender too, and nearly naked. They usually bear no very distinctive markings. The habits of the different species vary noticeably. All are active, although many of them live in concealment.

Fernald and Shepard (27, p. 248) declare that many of the Pyralididae are injurious but that few of them can be rated as serious pests throughout the country. One species, while not exclusively a pest of the Umbelliferae, is worthy of a thorough discussion.

Phlyctoenia ferrugalis Hübner.

The celery leaf-tier, Phlyctoenia ferrugalis Hübner, is listed by some authorities as Phlyctoenia rubigalis (Guenée) and is known as the greenhouse leaf-tier by many.

The species, which occurs also in Europe and Asia, appears in troublesome numbers in several regions of the United States and Canada. The most important insect pest of celery in the Sanford[2] district of Florida, it is sometimes serious in California and has been reported from Colorado and northern celery growing areas. Gould (41, p. 9)

---

[2] Sanford is the largest city in Seminole County, which is located in eastern central Florida.

states that the celery leaf-tier has caused damage in parts of Indiana, especially in those areas to which southern celery has been shipped during the winter and spring.

The celery leaf-tier spread to Canada, it is believed, in 1896 or 1897, probably from greenhouses in the United States. The first Canadian record of injury was reported from a large greenhouse in Toronto, Ontario. The Canadian Department of Agriculture (37, p. 11) reported an important infestation at Winnipeg, Manitoba in 1917. By the winter of 1918-1919 the leaf-tier had multiplied enough to cause outbreaks in many greenhouses in eastern Canada. Injury was reported from various parts of Quebec, New Brunswick, and Nova Scotia. Although Essig (24, p. 708) records the celery leaf-tier from British Columbia, Gibson and Ross (37, p. 11) declare such records doubtful, asserting that no injury has been reported there.

The celery leaf-tier causes its most severe damage out of doors in commercial celery fields, but several other vegetables as well as numerous flowers also serve as hosts. A complete list of the known hosts, including greenhouse plants, follows:

Flowers:

abutilon
ageratum
anemone
aster
azalia
begonia
canna
carnation
chrysanthemum
cineraria
cyclamen
dahlia
daisy
deutzia
fern
fever-few
forget-me-not
geranium
German ivy
ground ivy
hardy aster

heliotrope
justicia
Kenilworth ivy
lantana
lobelia
marigold
matricaria
mignonette
nasturtium
nodding thistle (*Carduus*)
pansy
passion flower
peony
plumbago (leadwort)
primula
rose
ruellia
salvia
snapdragon
sweet pea
thistle
tydaea
veronica
violet
wallflower
wandering jew

Vegetables:

beet
cabbage
cauliflower
celery
clover
cucumber
kale
lettuce
parsley
peas
spinach
strawberry
sugar-beet
tobacco
tomato

The celery leaf-tier also attacks weeds, including ragweed.

The moth has been described by various authorities as being grayish brown, pale reddish brown, and light yellowish brown. The wing expanse is from seven-tenths to eight-tenths inches (twenty mm.), but at rest the wings are so held that the moth measures only three-eighths of an inch at the widest part. Irregular dark lines mark the wings, particularly the forewings, which are pale clay brown suffused with reddish brown. The hindwings are paler than the forewings, being gray with darker margins.

The moths fly actively at night, resting quietly during the day on the undersides of leaves or in other sheltered places. If disturbed in the daytime they fly jerkily and for only very short distances.

The eggs are laid on the undersides of the leaves and sometimes on the stems. They are not distributed evenly

throughout the plant, the great majority occurring within the outer covering of leaves, toward the center of the plant. They are laid singly or arranged like fish scales in overlapping masses of from three to fifteen.

The pearly-white, coarsely reticulated egg is much flattened, so that it appears like a disc slightly raised in the center. The egg, which is about one-half millimeter in width, may be seen with the naked eye, and Gibson and Ross (37, p.12) suggest that it looks like the egg of the codling moth[3] due to its flattened appearance. These writers describe the egg as round in outline, while Essig (24, p.705) describes it as ovate. It hatches in from two to three weeks. Owing to the egg's translucency, the head of the larva may be seen through the shell as a dark spot before it hatches.

Although the larvae have five instars, they do not change greatly except in length. They are slender and when fully grown measure about three-quarters of an inch or slightly more (twenty millimeters) or slightly less. Gilbert and Popenoe (39, p.21) describe them as about half an inch long, not indicating whether or not fully grown.

When the larva first leaves the egg, it is a creamy white and partly transparent, with a few long white hairs.

---

[3] Carpocapsa pomonella, Family Tortricidae, (Also called Family Olethreutidae or Eucosmidae)

As it feeds, it takes on a pale green or pale yellow color, still remaining watery looking. In the fully grown larva a broad white band runs lengthwise over the back. Down the center of this white band runs a thin dark green stripe. The head is light brownish, marked with a few faint dark dots.

The larva, when about one-third grown, begins to web the foliage together with fine white silk and feeds within. The web is generally described as light or slight, but Frost (36, p.352) says that the leaves and flower buds are drawn together and tied with much silk. The parts of a single leaf may be tied together or the web may cover several leaves or often large masses of foliage. It is common to see two leaves tied together and find the caterpillar eating the under surface of the upper leaf.

Although the worms feed almost entirely on the under surface of the leaf, as they reach maturity they may eat out portions of the leaf conspicuously enough to spoil the appearance of the foliage and may even consume entire leaves. They sometimes attack the flowers and mine the stems toward the heart of the plant, in the case of celery cutting such deep grooves into the stalks that they cannot be eaten or sold. Summing up the commercial loss, Stone _et al._ (85, p.5) state:

> The pest prefers to feed on the tender succulent growth just above the heart of the plant, and such feeding results in injured leaves and stalks covered by webbing and castings from the worm's body.

> Besides the damage to the crop from actual foliage destroyed, the presence of the worms necessitates a closer stripping of the plants at harvest time to remove the injured leaves. Then also the accumulation of webbing and frass is objectionable and lowers the market value of the product.

When at rest the larvae hold the head and thorax curved around to the side of the body. If disturbed, they squirm actively and wriggle into their webs or fall, suspending themselves by silken threads.

The larvae usually pupate within their web, often forming an additional shelter by rolling over the edge of a leaf and fastening it with silken threads. Within, they spin thin cocoons of silk and change to pupae about three-eighths of an inch long. This stage is brown and shiny, growing darker as it matures. The length of the pupal stage is recorded by Metcalf and Flint (63, p.714) as ten to twelve days, and by Gibson and Ross (37, p.13) in Canada, as seventeen to twenty days.

These same authors report a corresponding difference in the length of the entire life cycle, Metcalf and Flint (63, 714) recording forty days and Gibson and Ross (37, p.13) observing seventy to seventy-five days at Ottawa during the winter months. If we assume the active season of the insect outdoors extending from the middle of May until the last of September, this would allow three generations per year in the first case and barely two in the second case.

This supposition is substantiated by O'Kane (66, p.186), who asserts that there are two or three generations per year outdoors. Essig (24, p.705), probably from observations in southern California, claims five or six generations. In greenhouses there is an indefinite number of overlapping broods.

In southern California, the maximum injury in celery fields occurs from the middle of August to the first of December and the minimum from March to July. In Florida the insects appear in destructive numbers only a few weeks before harvest. Weather conditions have a marked effect on the celery leaf-tier, high temperatures favoring its abundance. Hence the conditions usually accompanying the growing of winter celery in the south limit the seriousness of its damage in most seasons. Probably it is this factor that explains why it thrives so in greenhouses.

Control. The celery leaf-tier is controlled to a certain extent by natural factors, the operations of which should be encouraged by man. Birds, particularly the tree swallows, consume large numbers of moths. Dusting with pyrethrum, to be described later, disturbs these moths, causing them to fly around over the plants and fall prey to the swallows. Three hymenopterous parasites are important controlling factors of the leaf-tier. They are a

chalcid,[4] Trichogramma minutum Riley, and two braconids, Microgaster phthorinaeae Muesebeck and Rogas rufocoxalis (Gahan). The first named is raised commercially on a large scale for distribution.

Handpicking is advisable during light infestations or whenever it can be accomplished economically. The larvae, pupae, and adult moths should all be collected and destroyed.

As stated above, the caterpillars rarely cause serious damage in Florida until a few weeks before harvest. Consequently, some growers harvest their celery early, thinking the loss from the decreased yield to be less than the expense entailed by sprays and labor. An examination of the most mature plants of the crop will tell when an outbreak is imminent, as the moths always prefer to lay their eggs on these plants.

Immediately after the harvesting, fields which have been infested by the celery leaf-tier should be plowed. There remain in such fields both larvae and pupae which have been brushed accidentally or removed purposely from the plants during harvesting. The outer leaf stalks, being unmarketable, are stripped from the plants and left in the fields. As the stalks do not dry up for some time, they often harbor the insects long enough to enable them to complete their development and lay their eggs on neighboring plants not yet harvested.

---

[4] Some authorities place this species in a separate family, Trichogrammidae.

From experiments made by Stone et al. (85, p.6) in Florida we learn that:

> Counts made in a field having 50 worms per plant showed that as many as six larvae may be left on the strippings from each plant.

Other experiments by the authorities cited indicated that when pupae were covered with one-half inch of soil, only one-third emerged as moths, and that no pupae were able to complete their development when covered by more than one inch of soil. They further state (85, p.7) that field observations by Dayton Stoner, of the United States Bureau of Entomology, and R. L. Miller, formerly of the Florida State Plant Board have confirmed the results of their experiments.

During the last twenty years washing machines which clean the celery for market have come into common use. As the celery is conveyed through the machine on an endless belt, it is sprayed from above and below by water under pressure, which frees the stalks from webbing, dirt, spray residues, and some of the larvae. Tests indicated that water sprayed under a pressure of fifteen pounds removed proportionately few larvae and that to rid the stalks of even seventy percent of them a pressure of fifty-five pounds was needed. Although perfect removal is not obtained, such washing processes make the celery a more readily salable market product.

Numerous sprays and dusts, both arsenical and non-arsenical, have been used to control the celery leaf-tier. Stone et al. (85, p. 8-9) have made experiments to determine how long before the harvest it is safe to apply arsenicals. In a maturing celery plant the older leaf stalks wither and drop, making room for the newer ones. The investigators labeled the individual leaf stalks of sample plants of both winter-grown and spring-grown celery to determine the length of life of each stalk. Table I shows the results of their experiments with a plant grown in the winter from the time it was transplanted to the field until ready to be harvested for market. Fifteen leaf stalks died and fell off during growth, ten were removed in the field by the harvesters, and fifteen stalks remained to be sent to market. This plant took nearly five months to mature, compared to the spring-grown plant which they tested, which took one and two-thirds months less to develop. The statistics of the latter experiment, given in Table II, show that almost as many stalks developed, dropped during growth, were stripped at harvest, and remained to be sold as in the winter-grown plant.

The important fact to be noted from both tables is that even the oldest of the stalks crated for market was only from five to six weeks old. The happy conclusion, that arsenicals may safely be used until six weeks of harvest, does no good in the case of the celery leaf-tier, which, as we have stated,

TABLE I

GROWTH OF CELERY PLANT IN WINTER (from Stone *et al.*)

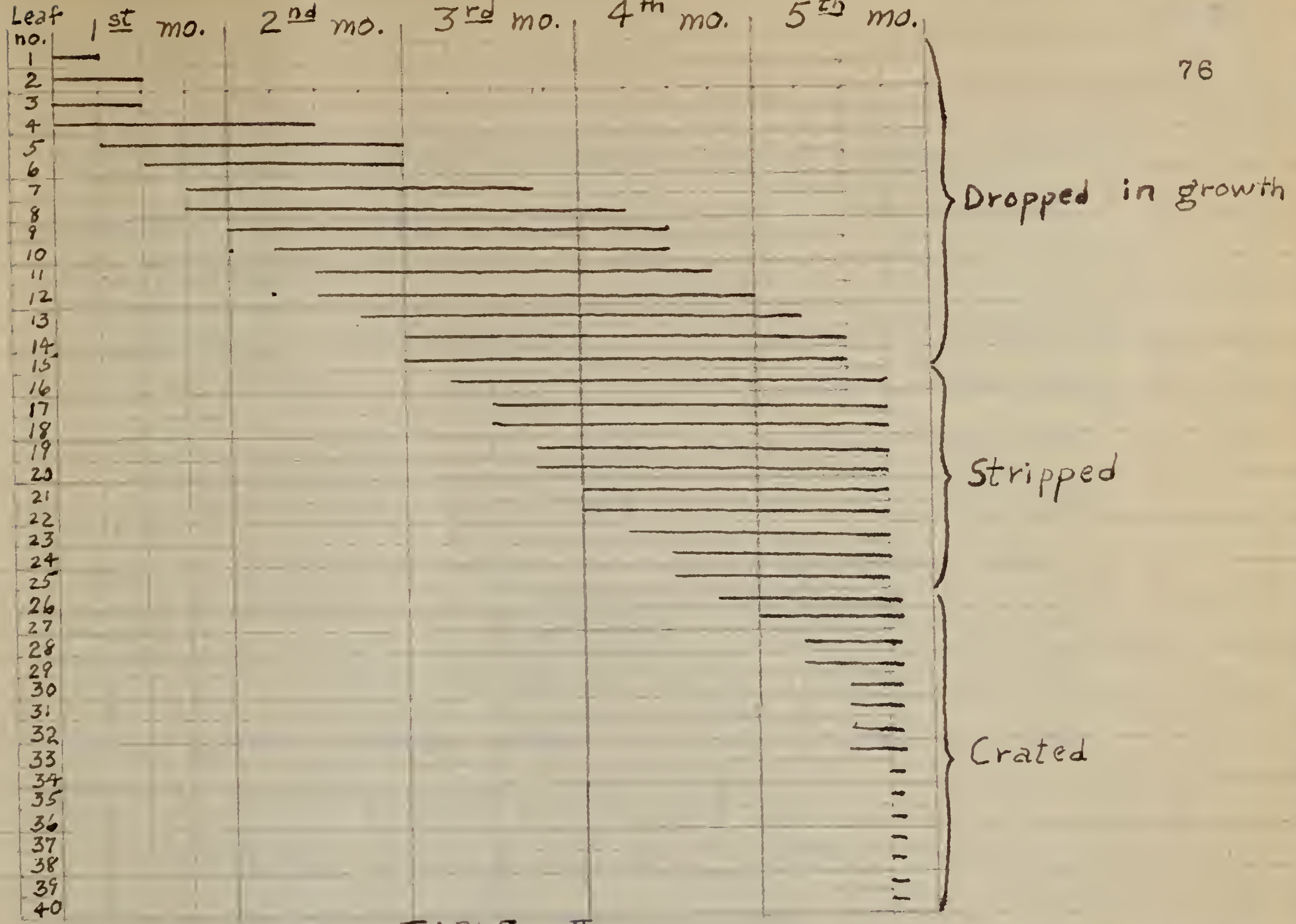
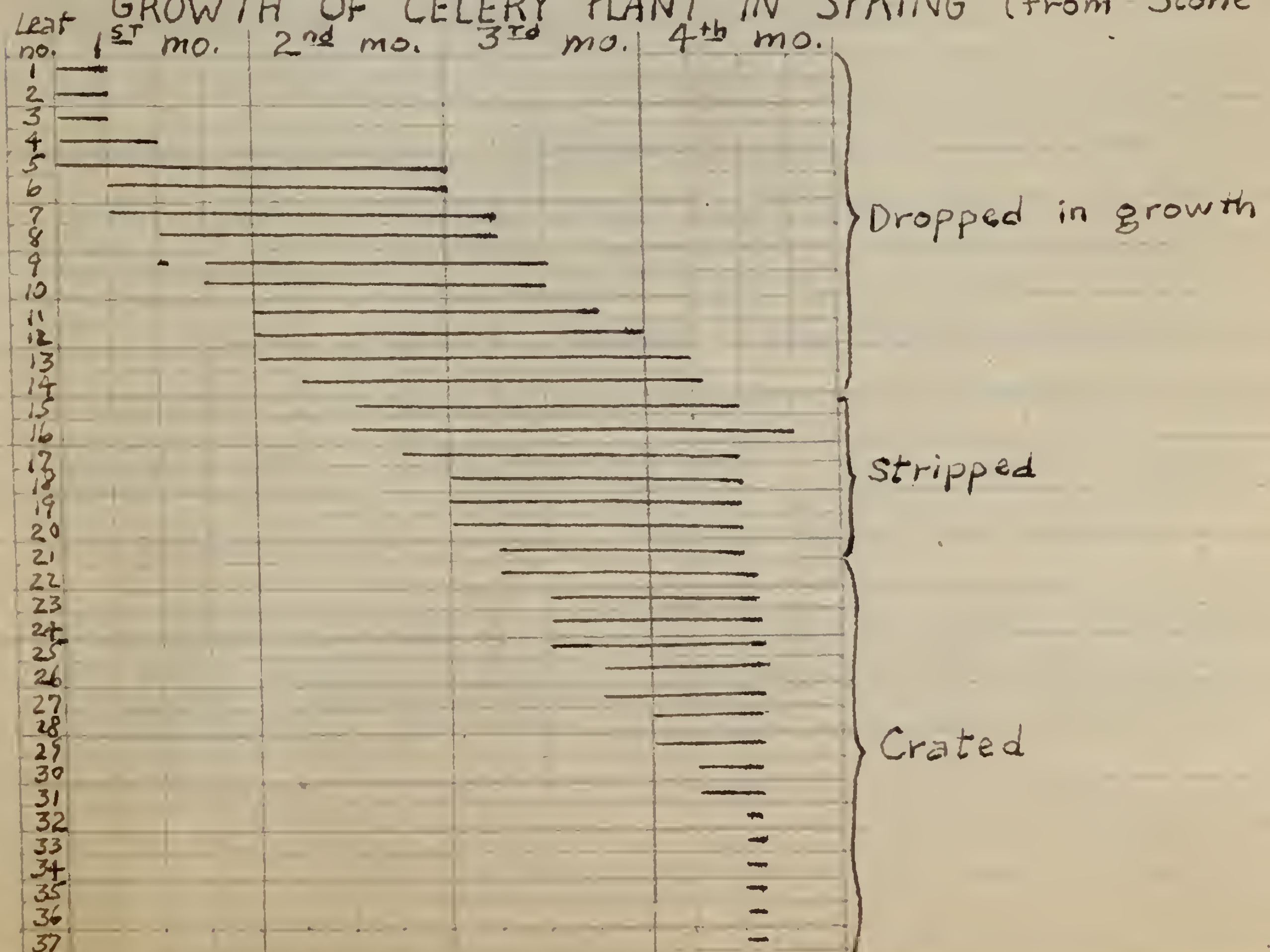


TABLE II

GROWTH OF CELERY PLANT IN SPRING (from Stone *et al.*)



rarely becomes a serious problem until shortly before harvest.[5] Arsenicals are advised for those of the many other hosts of the celery leaf-tier, the above ground parts of which are not being grown for human consumption. A lead arsenate spray is advised by O'Kane (66, p.186), Gilbert and Popenoe (39, p.21), The Garden Encyclopedia (81, p.726), and by Essig (24, p.706), who says that control may be obtained by spraying with three pounds of arsenate of lead to one hundred gallons of water. Metcalf & Flint (63, p.715) proclaim the effectiveness of a careful dusting with a mixture of one part arsenate of lead to four parts of dusting sulfur, warning that such a mixture will burn certain delicate greenhouse plants.

Stone et al. (85, p.8) have made laboratory tests to determine the relative efficacy of different arsenicals in controlling the leaf-tier on celery. Plants were carefully sprayed at the rate of one hundred gallons of the various mixtures to the acre. Colorimetric prints of the leaves showed that they obtained a more even distribution of the spray over both upper and under sides of the leaves than can be obtained by commercial growers. Even under these ideal conditions, large amounts of the arsenicals were needed, four pounds of Paris green and ten pounds of lead arsenate, each to one hundred gallons of water, being necessary for control.

---

[5] These data are made use of in the cases of the semi-tropical army-worm, Eridania xylomyges, page 108, and the celery looper, Autographa falcifera, page 97, both of which may be controlled by arsenicals applied before six weeks of harvest.

Calcium arsenate, at as high a rate as eight pounds to one hundred gallons of water, was apparently useless. In these experiments they used sprays rather than dusts, because, they state, unpublished data of B. L. Boyden and J. O. Clark show that arsenical dusts leave greater residues on the celery plants than do the sprays.

Of the non-arsenical poisons, nicotine and derris have been found useless both as sprays and dusts. Pyrethrum, however, gives excellent control of the celery leaf-tier without injuring the tender hearts of the celery plants. In 1944, White and Doolittle (100, p.25) of the United States Department of Agriculture advised dusting with one pound ground pyrethrum flowers (1.3 percent total pyrethrin content) to three pounds talc, pyrophyllite or tobacco dust. The ingredients are shaken in a closed can containing several stones about one inch in diameter, to insure thorough mixing.

The pyrethrum dust method was developed by Stone _et al._ (85, p.10-23) in Florida for the control of the leaf-tier on celery. We here present a summary of their experimental work with this method and their advice concerning its correct application.

The advantage of dusting with pyrethrum over spraying is the result of the manner of growth of the celery plants and the area of the plants upon which the females prefer to lay their eggs. The several varieties[6] of celery commonly grown in Florida are characterized by a very compact growth.

---

[6] Golden Self-Blanching and several strains of Special.

Growers encourage the thick growth by setting the plants out in rows which are twenty-eight or thirty inches apart, and only three or four inches apart in the rows. For these reasons the dense outer covering of leaves shields the heart of the plant from a spray. It is on the heart of the plant, though, that the poison is most needed, as the adult females most often lay their eggs here. The larvae do their chief damage to this region, which is the only part of the plant, in fact, shipped to market. The workers determined that on seventy-five field grown plants 2,422 eggs were laid, sixty-eight percent of which were found around the heart.

Colorimetric prints were made, using the method originated by Hamilton and Smith,[7] of leaves from all parts of plants which had been sprayed and plants which had been dusted. The spray was found to have reached only the outer roof of leaves, and adhered well only on the upper surfaces. Even under high pressure, it could not penetrate this shield. The dust, on the other hand, while giving a more even distribution, tended to settle toward the heart of the plant. Consequently, pyrethrum dust rather than spray should be used on celery to give adequate control of the leaf-tier.

Laboratory experiments showed that pyrethrum dust killed the moth stage when applied directly on the moths in an

---

[7] C. C. Hamilton and C. M. Smith, "A Colorimetric Method for Showing the Distribution and Quantity of Lead Arsenate upon Sprayed and Dusted Surfaces," Journal of Economic Entomology, 18:503, 1925.

enclosed area. In the open air, however, dusting only annoys the moths, causing them to rise from the plants and be carried away by the breeze, with great likelihood of their infesting nearby fields of younger celery. Dusting is of some value for the moths, if tree swallows, which are credited with consuming many of them, are present in the region. The moths, disturbed by the poisonous dust, are easy prey for these birds, which swoop low over the fields.

Statistics were taken on a field having 135 moths per 300-foot row. The day after dusting with pyrethrum only ten moths per row remained, but no dead ones could be observed. Bordering fields, however, showed an increase of ten moths per row, and only nine days later the dusted field became so badly reinfested with moths that another application of dust was necessary.

Laboratory experiments dispelled the opinion of certain growers that pyrethrum possessed much effectiveness against leaf-tier eggs. Under ideal laboratory conditions, pyrethrum placed directly upon eggs prevented only twenty percent from hatching. Untreated control eggs all hatched. In the case of plants brought in from a thoroughly dusted field, the kill was even lower, as might be expected, being only six percent.

Thus while the usefulness of pyrethrum dust against adults and eggs is at most very questionable, its serviceability against the larvae is indisputable. Only a small amount of the dust on the caterpillar's body brings on paralysis and

death. The smallest possible amount of dust which will cause death is still unknown, but it is believed to be very little. The quantity, of course, differs with the size of the larvae and it is well to apply the dust while they are as small as possible, before they begin to conceal themselves in the webbed leaves or in the stalks.

When the larvae are two-thirds grown, the best kill that can be hoped for under the most ideal spraying conditions is sixty-five percent. A comparison of the percentages of small larvae and larvae more than half grown during a series of experiments indicated an average of twenty-two percent greater kill among the small larvae. As soon as the moths have disappeared from the plants it is time to start daily inspection of the hearts and dust as soon as larval injury becomes evident.

Hand dusters should not be used to apply the dust to large crops, for with them it is not practically possible to penetrate the outer canopy of leaves. Better results are obtained with horse or mule drawn traction dusters, arranged to cover four rows at a time, a separate pipe and nozzle for each row. To prevent a discontinuous flow of dust and the resulting uneven distribution, models which mix air with the dust in the fan chambers and have a force feed from the hopper are advised.

An important factor in the proper dusting technique is the adjustment of the duster pipes. The end of the pipe should not be above the celery plant, but should extend below

the heavy outer covering of leaves. If this is done, the dust will be emitted close to the heart of the plant, where it is most needed. Minimal injury results to the plants in spite of their thick growth, and the pipes may be drawn down through the entire celery rows, four rows at a time, with hardly an adjustment necessary over an entire field, due to the precise planting methods employed by the growers. A plow-like device fastened to the end of the pipe to open the foliage before it, was found by the investigators not to compensate for the extra work involved in keeping it adjusted.

A calm day must be chosen for the application of pyrethrum dust, as it is a very light material and floats away on the slightest breeze. It has been a practice of farmers, when dusting on windy days, to drag along a cloth trailer over the plants behind the duster, to keep the dust from blowing away. As an experiment, the workers dusted with and without a cloth trailer during a thirteen mile per hour wind. The trailer gave no advantage, and the kills in both cases were low. Dusting on a windy day will never give a kill of over sixty-five percent, in fact, and the results are generally much poorer.

If there are several consecutive windy days when dusting is urgent, the best time is after sundown or in the early morning. If dew or other moisture is on the foliage, dusting should be delayed, for the dust will then cake around the nozzle openings and will be forced out onto the plants in

scattered lumps. Generally higher kills result on warmer days, probably, as the authorities cited suggest, because the larva's increased activity multiplies its chances of being hit by the poison then.

Pyrethrum dust must be applied for the celery leaf-tier in two treatments, one-half hour apart. One treatment does not give good control. The larvae it does not kill, however, are sufficiently annoyed by the dust to wriggle from their webs, exposing themselves to the second application of dust. The data obtained from a group of experiments showed an average of eleven percent increase in kill resulting from the second application, or the added destruction of five larvae per plant.

In the Sanford area of Florida, up until 1927 only closed-flower pyrethrum was used, being employed undiluted at the rate of forty to fifty pounds an acre. From 1927 to 1929 the price of pyrethrum jumped from thirty to fifty cents per pound. Further experiments were made with Japanese pyrethrum, a far less expensive mixture prepared by grinding together both open and closed pyrethrum flowers. Tests showed that dust containing only fifty percent of this pyrethrum gave as good control of the leaf-tier as the same quantity of undiluted pyrethrum. They experimented with mixtures containing half pyrethrum and half lime, and with mixtures containing half pyrethrum and half sulfur. They chose lime for its inexpensiveness and good dusting properties and sulfur for its usefulness in combating red spider mites. Under the

same experimental conditions the highest percentage kill of larvae, twenty percent of which were over half grown, was ninety-one percent, given by a mixture of half pyrethrum and half lime, applied in two doses of twenty-seven pounds an acre each.

In a humid atmosphere, pyrethrum dust tends to lump and harden, so freshly ground dust should be used if available. The lime or sulfur should be mixed in a container with stones as described above (page 79) just before it is used, as it has not been determined how long its power will be preserved in such a mixture.

Other control measures are advanced for the celery leaf-tier in greenhouses. Fumigation with calcium cyanide, greenhouse grade, will effectively rid the houses of the moths.

For a complete discussion of calcium cyanide fumigation see C. A. Weigel, Calcium Cyanide as a Fumigant for Ornamental Greenhouse Plants. Washington, D. C.: United States Department of Agriculture, Department Circular 380, April 1926, 16 pages.

A short description of calcium cyanide, ($Ca(CN)_2$) is given by Metcalf and Flint (63, p.257):

> .... It is lower in cyanide content than sodium or potassium cyanide. One form in common use contains from 40 to 50 percent calcium cyanide and gives off its gas very slowly. It will give off about half as much hydrocyanic acid gas as an equal amount by

> weight of sodium cyanide. Another form of dust contains 88 percent calcium cyanide and will yield about 90 percent as much gas an an equal weight of sodium cyanide. In this form of dust the gas is generated very rapidly upon exposure to the air. No acid is required to generate the gas from calcium cyanide dusts, the necessary reaction taking place when it is simply exposed to the atmosphere.

The calcium cyanide dust is sprinkled one-eighth of an inch or less thick over the greenhouse floor, which may first be covered with newspapers if desired. The rate of application depends upon the hardiness of the plants in the house, the construction of the house, and the percentage of calcium cyanide the dust contains. If an 88 percent dust is used, a safe amount to start with is one-eighth of an ounce for one thousand cubic feet. A 48 percent dust should be used at about twice this strength. The rate in either case should be gradually increased from one treatment to the next if the moths are not killed, examination of the tenderer plants being made for evidences of burning. The minimal rates indicated can probably be doubled safely. The greenhouse is then tightly closed and must not be opened again for two or three hours. By morning almost all of the gas fumes will have vanished.

The eggs,larvae, and pupae are not injured by these calcium cyanide fumigations. Consequently the treatment

should be repeated weekly for a month or five weeks, if the plants can endure it, to eradicate this pest completely from the greenhouses.

The following spray mixture, developed by Gibson and Ross (37, p.14), proved highly successful in greenhouses of florists in Ottawa, Montreal, and Halifax:

Soluble sulfur..............	1 ounce by weight
Nicotine sulphate	1 fluid ounce
Water	6 gallons

In bad outbreaks, three applications, one a week, were required to control the leaf-tier.

Oecophoridae.

The smooth heads of the members of this family bear antennae which usually have a comb of bristles on the scape. The wings of the moths are rather broad, on some species even expansive. The hind tibiae bear rough hairs above. Most of the caterpillars feed under the concealment of leaves or blossoms which they have webbed together.

The Oecophoridae is a large family, says Matheson (61,p.292), especially abundant in Australia, where over one thousand species have been recorded. One member of this group is an important pest of the Umbelliferae.

Depressaria heracliana (DeGeer).

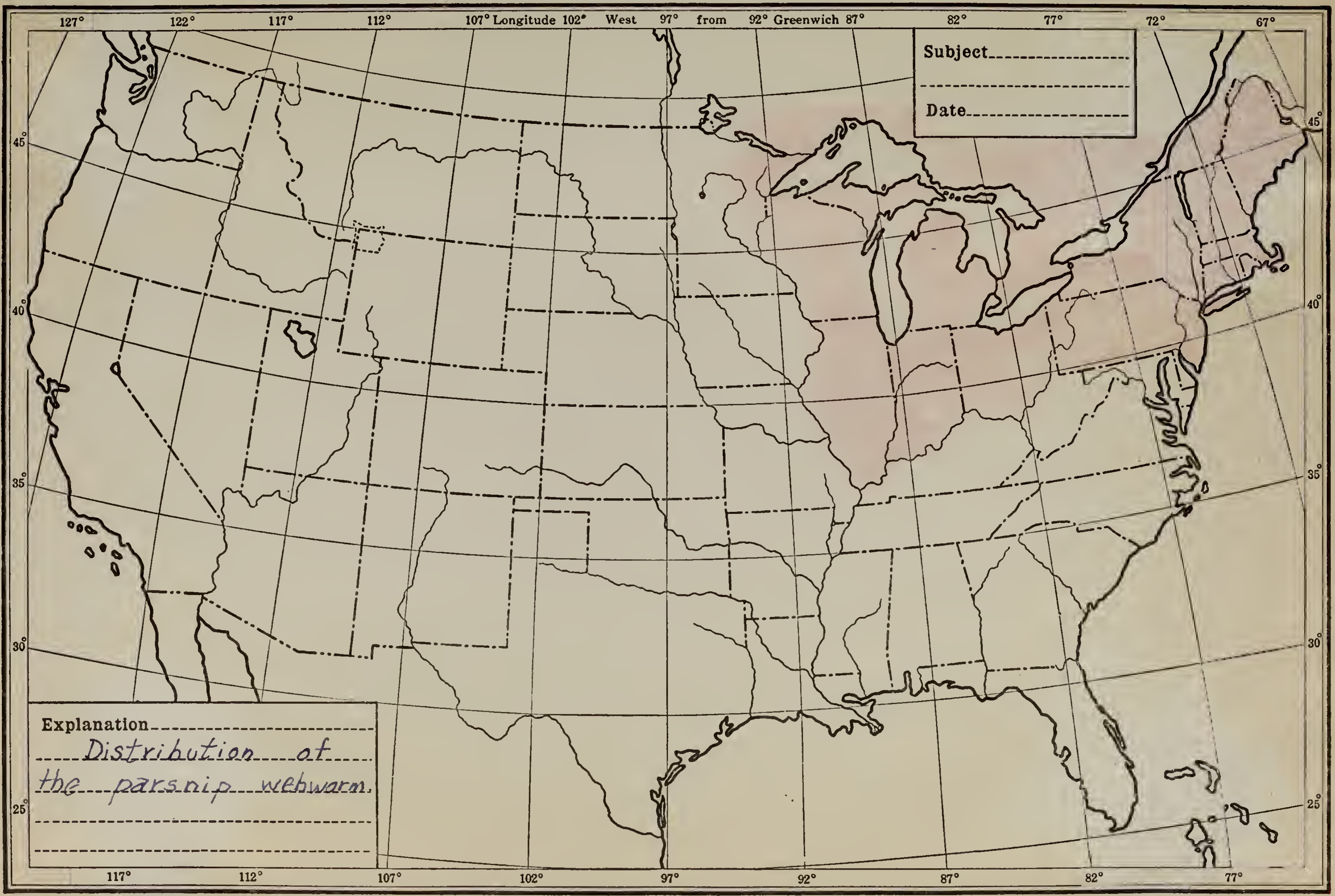
The parsnip webworm, Depressaria heracliana, occurs in the northern United States east of the Mississippi River and in southern Canada. It damages parsnip, celery, carrot, and other Umbelliferae including such common weeds as wild parsnip or cow parsnip and wild carrot.

The adult is a small dark gray moth with a wingspread generally of one inch, but sometimes approaching one and one-half inches. The moths emerge from late July and early August in New York to the latter half of August in Nova Scotia. Brittain and Pickett (2, p.52) state that in Nova Scotia a few may not appear until as late as the middle of September. Soon after emergence, the moths seek shelter under loose bark or in other protected places and hibernate. They appear again in the spring and lay large numbers of eggs singly on their host plants. Oviposition occurs on leaves, stems, and especially on the sheath surrounding the developing flower heads. The period of oviposition extends over a fairly long interval, as Brittain and Pickett (2, p.252) report the finding of newly hatched larvae late in July. About a week is spent in the egg state.

The small caterpillars are yellowish to grayish-green, covered with small black spots and short hairs. The largest are only about three-fifths of an inch long, say Metcalf and Flint (63, p.508). The young larva ties together the unfolding blossom heads,constructing a delicate tunnel of

On the following page is a map which shows the ditribution of the parsnip webworm.

McKinley's Geographical and Historical Outline Maps. No. 176b. The United States. (State boundaries.)



Explanation
Distribution of
the parsnip webworm.

Copyright, McKinley Publishing Co., Philadelphia, Pa.

silk within which it feeds. When the head finally bursts open it may be nothing but a mass of webbing and caterpillars. The larvae interfere seriously with the production of celery and parsnip seed and also feed upon the leaves. Frost (36, p.352) claims that they feed upon the flower heads and seeds more than upon the leaves.

After the larvae have consumed the flowers and unripe seeds and become nearly mature, a process which takes about four weeks, they crawl down the stem usually to the axil of a leaf, eat their way through the hollow stem, and feed upon the soft lining of the interior. The entire larval life averages just under five weeks and includes a total of five instars.

The larvae pupate in their mines or inside the hollow stem in light cocoons of silk and excrement. Brittain and Pickett (2, p.52) assert that the pupal instar continues for three weeks. There is only one generation each year.

Control. It is often impossible to grow umbelliferous crops far removed from such common weeds as cow parsnip. This and other wild host plants should be kept down in neighboring fields at least. Handpicking the caterpillars from the infested flower heads is effective on a small scale, and the injured heads should be cut and burned before the moths emerge in July and August.

The long period of oviposition and the concealment afforded by the webbing make control by spraying or dusting difficult. Although such a method would not be entirely satisfactory, The Garden Encyclopedia (91, p.871) advises

spraying or dusting with calcium arsenate, and Metcalf and Flint (63, p.510) recommend calcium arsenate at the rate of six to eight pounds an acre. Frequent dusting with a mixture of two pounds of arsenate of lead to eight pounds of hydrated lime is said to be of considerable benefit.

Noctuidae (Phalaenidae) (Owlet moths).

These stout-bodies moths bear typical threadlike antennae. Their strong front wings are narrow and somewhat elongated. When at rest the wings are folded over the abdomen, giving the insect a triangular outline. The Noctuidae are chiefly nocturnal and are attracted to lights. The fact that their eyes glow in the dark has given rise to their popular name -- owlet moths. The larvae, which are usually naked, as a rule feed by night.

This is the largest family of moths in the United States, and its members are plentiful everywhere. Of the nine members of the Noctuidae which have been recorded as injuring members of the Carrot Family, only two show any preference for this group. Neither of these two is of great importance.

Agrotis c-nigrum Linnaeus.[§]

Agrotis c-nigrum is popularly called the spotted cutworm

[§] Often placed in the genus Noctua.

and less commonly the corn cutworm. It is one of the most prevalent cutworms in northern United States. The spotted cutworm is a pest also in Canada, Alaska, Europe, and Asia.

It is said to attack all kinds of garden and root crops, including celery and carrot. Some of the more common hosts of the species are:

apple (leaves)
beet
cabbage
corn
clover
cranberry (leaves, blossoms)
currant
ferns
grasses
mangel
tobacco
tomato, (leaves, fruit)
violet (" , blossoms)
wheat

The spotted cutworm feeds on wild ferns and grasses, goldenrod and other weeds. Chittenden (9, p.58) found its most common host plant to be chickweed.

The moths have brown forewings tinged with red or purple. In the middle of the anterior margin of each forewing is a black area containing a light colored V-shaped indentation.

The full-grown larvae of the spotted cutworm are about one and one-quarter inches long. They are pale underneath and darker above, bearing dorsally a double row of black finger-like markings which become more noticeable on the posterior segments.

Agrotis c-nigrum is one of the species of cutworms which sometimes climbs up into host plants to defoliate them. It may also sever plants near ground level after the usual manner of cutworms, being capable of chewing through stalks an inch in diameter. It is most active in the early morning and early evening. The spotted cutworm has a habit of migrating much as do army-worms, and consequently often attacks suddenly and in large numbers. More detailed information on the various stages of this species and on the damage caused by its larvae is given by Chittenden (9, p. 54-58).

Control. Agrotis c-nigrum may be controlled rather well by the standard measures in use against cutworms. Such measures include poisoned bran baits, trap lights, fumigation (when plants in greenhouses are attacked), and spraying with such poisons as arsenate of lead. By far the most effective method of control is the use of various sorts of poisoned baits, as described by Lacroix (57, p.100-101) and Chupp and Leiby (10, p.81,111).

Agrotis unicolor Wlk.

Agrotis unicolor Wlk. is listed by many writers as Noctua clandestina Harris. It is known as the well-marked or W-marked cutworm. This species has much in common with the preceding one, for it is a general feeder with climbing tendencies and attacks buds and blossoms as well as leaves.

The well-marked cutworm occurs throughout northern United States and in Canada. Celery has been listed among its host

plants, a few of the commonest of which are apple, bean, cabbage, clover, grasses, lettuce, peach, plantain, tobacco, and wheat. The moths are so similar to the moths of many of the other cutworms that they cannot be described without going into great detail. The mature larvae are about one and one-half inches long and grayish-green, dull brown, or dark gray in color, mottled with darker areas. The larvae hibernate and in the spring eat ravenously for a short while before they pupate in the soil. Lacroix (57, p.95) feels that two generations may occur annually in Connecticut.

The well-marked cutworm may be controlled by the means suggested for the control of the preceding species. A third species of cutworm, Porosagrotis orthogonia Morrison, will be mentioned presently.

Autographa brassicae (Riley).

The cabbage looper, a native species, is widely distributed throughout the United States, particularly east of the Rocky Mountains. Its range extends down into Mexico, and although several outbreaks of it have occurred in Canada, it is not common there yet.

This species is rather specific for the Cruciferae although it sometimes attacks celery and parsley as well as other vegetables and flowers. Its economically important cruciferous

hosts are:

broccoli
brussels sprouts
cabbage
cauliflower
collards
horseradish
kale
kohlrabi
mustard
radish
rutabaga
turnip
water cress

Cruciferous flowers attacked by the cabbage looper include alyssum, candytuft, honesty, rock cress, stock, and wallflower. Some of the non-cruciferous vegetable hosts are asparagus, beet, lettuce, pea, potato, and tomato. Among the non-cruciferous flower hosts are calendula, carnation, chrysanthemum, cineraria, geranium, German ivy, mignonette, nasturtium,and smilax. As far as can be determined, dock is the only weedy host reported.

The moths bear a resemblance to the moths of cutworms. They are medium-sized, dull gray or brown in color, and measure from four-fifths of an inch to an inch in length. They have a wingspread of nearly one and one-half inches. The forewings of these moths are transversely mottled and bear centrally an irregularly shaped though clearly defined silvery-white spot.

The cabbage looper moths are seldom seen, for they are active only at night. It is then that they lay their numerous, tiny, round, greenish or white eggs singly on leaves.

The caterpillars are greenish with white or yellow longitudinal stripes. When mature they measure from one and

three-eighths to over one and one-half inches long. The caterpillars are known as semi-loopers, for they bear only the first two pairs and the last pair of prolegs. The middle part of the body lacks legs and is typically humped up both when the caterpillar is at rest and when it is moving.

The larvae eat irregularly shaped holes in the foliage of their hosts. They are found most often on the under surface of the older and lower leaves. There, or on some nearby object, they spin delicate silken cocoons within which they pupate. Doane (21, p.212-214) differs from other authors in stating that the pupal stage is passed in a thin cocoon in the soil. Three, four, or more broods of the cabbage looper are produced in a single year, depending upon the climate. The winter is passed in the pupal stage.

Control. Several natural factors combine to destroy large numbers of the cabbage loopers each year. Predators feed upon them freely and at least six hymenopterous insects parasitize them. Four of these insects are braconids: Apanteles glomeratus (Linnaeus), Apanteles laeviceps Ashmead, Microplitis brassicae Muesebeck, and Rogas rufocoxalis (Gahan). The other two are a chalcid, Litomastix truncatellus, and an ichneumonid, Itoplectis conquisitor (Say). In addition, sometimes almost a whole brood of caterpillars may be wiped out late in the season by a wilt disease which causes their bodies to rot.

The gardener will often find it necessary to assist nature in keeping the cabbage looper in check by handpicking, burning all garden refuse, and cultivating regularly to kill the pupae. For quick results, various poisons are recommended. The poisons include arsenical and fluorine compounds, hellebore,[9] rotenone, and pyrethrum. Directions for the preparation and application of these poisons are given by Crosby and Leiby, (17, p.21-22, 102), Chupp and Leiby (10, p.23-26), Gould 41, p.5-6), and, under greenhouse conditions, by McDaniel (62, p.77).

Autographa falcifera (Kirby).

The celery looper, Autographa falcifera (Kirby), the specific name often being spelled falcigera, is referred to by some writers as Autographa simplex and by others as Plusia simplex Guenée.

The celery looper is distributed throughout the United States, and attacks(in addition to celery) beans, cabbage, lettuce, sugar-beets, and succulent weeds.

The adult is a moth resembling the adults of several of the cutworms. It is a large moth with purplish-brown forewings which are not scalloped. Comstock (12, p.687) describes the forewings as marked with metallic-colored scales, the form of the markings being a silvery spot, shaped somewhat like a

---

[9] Usually the powdered roots of Veratrum album, a European plant.

comma, near the center of the wing.

The larvae pass the winter under the shelter of leaves or other objects in a partly grown condition. They are smooth-bodied pale green caterpillars, narrowing gradually to the head. They bear rather indistinct longitudinal stripes of a lighter color and have a row of tiny black spots along each side of the abdomen. Each spot has a white dot in its center which marks the opening of a spiracle. The larvae measure from one to one and one-quarter inches long. They are semi-loopers, having three pairs of prolegs instead of the usual five pairs and consequently crawl with a looping movement as described for Autographa brassicae, the cabbage looper. The occasional feeding damage of this species is on the foliage. Peairs (70, p.265) has found that there are three generations a year through the middle part of the celery looper's range.

Control. Control with arsenicals is possible, O'Kane (66, p.179) advocating the use of arsenicals, especially Paris green and lime, which can be washed from the leaves when the stalks of celery are ready to go to market.

A combination of Bordeaux mixture and arsenicals, as described for the semi-tropical army-worm, is of use. However, even with the washing facilities available, arsenicals are likely to be objectionable at times, and rotenone has proved a good substitute. Gould (41, p.18) reports that a mixture of rotenone and sulfur, applied as a dust, is effective.

Mamestra legitima Grote.

The striped garden caterpillar is placed in the genus *Polia* by some authorities. It may be found throughout Canada and in the United States from Maine to Oregon and south to Kansas, Virginia, and the Gulf States. It is a general feeder but shows some preference for such cruciferous plants as cabbage, collard, rape, rutabaga, and turnip and for asparagus, blackberry, peas and other leguminous vegetables, tobacco, and violet. It has been found on such weeds as goldenrod and milkweed. Dirks (20, p.88) states that grass is probably the normal food of the larvae. Several authors agree that the damage done by the striped garden caterpillar is of minor importance.

The moths have a wing expanse of a little over an inch and one-quarter. Their gray forewings are covered by a pattern of velvety brown and black spots. Their hindwings are fawn-colored with fairly prominent veins.

The bright black and yellow striped caterpillars have been known to feed upon leaves, flowers, and seeds. They are rarely abundant enough to call for any other control than handpicking. Should they ever need insecticidal control, the measures employed against the cabbage looper will destroy them also.

A description of each of the stages of the striped garden caterpillar and a discussion of its life history, natural enemies, and artificial control is given by Chittenden (9, p.28-32).

Mamestra picta Harris.

The zebra caterpillar is placed in the genus Ceramica by some authorities. In the United States it is found from the Atlantic States westward to Nebraska, and Colorado. It occurs commonly in Canada, particularly in Nova Scotia, where it has occasionally caused serious damage.

Mamestra picta feeds on various garden crops including celery. Other common hosts are apple, bean, beet, cranberry, mangel, peas, potato, spinach, and turnip.

The moths have purplish-brown forewings with a light mark near the center of each. The hindwings are light and bordered with tan. The wingspread varies from one and one-half to one and three-quarters inches. The naked caterpillars are decorated with gay black and yellow longitudinal stripes and reach a length of about two inches. By night they feed upon the leaves of low-growing plants. At maturity they enter the soil and form earthen cocoons in which they pupate. Two generations occur annually. The second generation is by far the more destructive of the two and hibernates as pupae.

Control. Handpicking is usually the only control necessary. A serious outbreak requires the application of arsenicals as described for the cabbage looper. Brittain and Pickett (2,p.14) give directions for controlling the zebra caterpillar with insecticides. They caution that in order to give best results the poisons must be applied soon after the larvae hatch, for the large caterpillars are difficult to kill.

Papaipema nebris (Guenée).

The common stalk borer is often described as *P. nitela* or *P. nebris nitela.* It has formerly been considered as belonging to the genus *Hydroecia* and the genus *Gortyna.*

This species occurs throughout Canada and in the United States in every state east of the Rocky Mountains. Reports indicate that its damage is most serious in a belt extending from Connecticut and into Illinois and Michigan, westward through North Dakota to British Columbia.

The common stalk borer damages celery as well as such other plants of economic importance as:

barley
bean
blackberry
blue-grass
corn
egg plant
oats
potato
raspberry
rhubarb
spinach
timothy
tomato
wheat

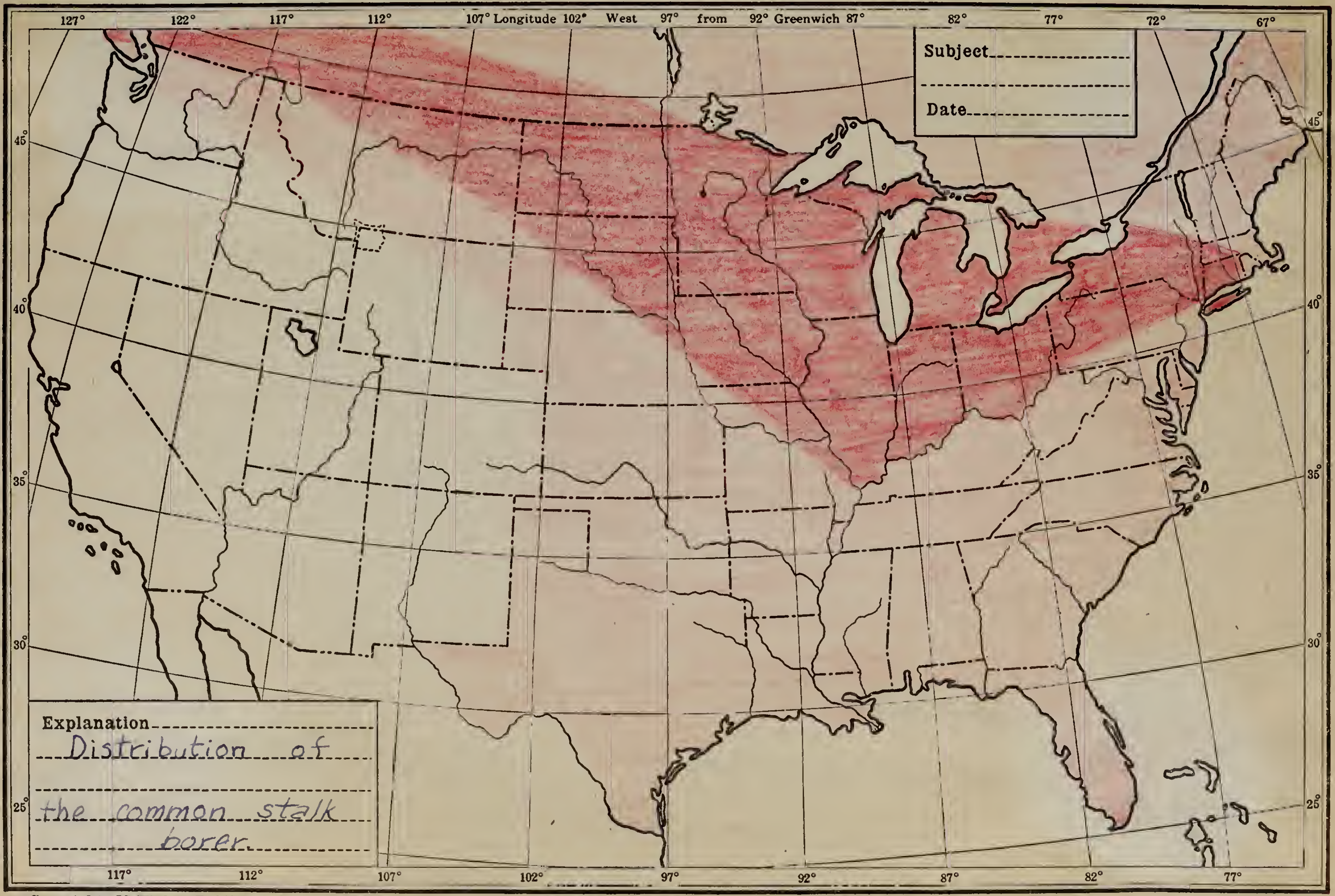
It attacks the new growth of apple, currant, grape, peach, willow, and similar plants. It readily feeds on burdock, cocklebur, pigweed, and ragweed. Flowers listed as hosts are:

ageratum
aster
calendula
castor bean
chrysanthemum
coneflower
cosmos
dahlia
delphinium
gaillardia
gladiolus
hollyhock
lily
monarda
nicotiana
oenothera
peony
pholx
salvia
snapdragon
sunflower
yucca
zinnia

It may be summed up that the common stalk borer will attack any fleshy stem that is thick enough to hold it.

On the following page is a map which shows the distribution of the common stalk borer. Intensity of coloration indicates intensity of common stalk borer populations.

McKinley's Geographical and Historical Outline Maps. No. 176b. The United States. (State boundaries.)



Subject

Date

Explanation Distribution of the common stalk borer.

Copyright, McKinley Publishing Co., Philadelphia, Pa.

The adult is a gray or grayish brown medium-sized moth with a wing expanse of about one and one-half inches. The forewings are marked with white lines and are slightly darker than the hindwings. The moths emerge in late summer or early fall and lay eggs on the stems or leaves of the host plants. The winter is passed in the egg stage.

The slender naked caterpillars are gray changing to cream-colored and bear narrow longitudinal brown stripes. They tunnel in hollow or pithy stems until the plants wilt and break off. Many entrance and exit holes are usually found in a stalk, for the larvae are active and restless, rarely satisfied to remain in one plant long. They pupate within the burrows. Only one brood is produced annually.

Control. Unfortunately, cultural practices alone must be relied upon to keep the common stalk borer in check. As the insect is an internal feeder, poisons are ineffective. Where possible the borers should be cut out with a knife or the infested parts of plants cut and burned. It is particularly important that garden refuse be prevented from accumulating. Weedy hosts should be eradicated from the vicinity of crops, and clean cultivation should be practised at all times.

Porosagrotis orthogonia Morrison.

The pale western cutworm causes the greatest amount of damage in Montana, western North Dakota, and Alberta. It is also common in South Dakota, western Nebraska and Kansas, Wyoming, Colorado, Utah, New Mexico, and Arizona. It has been found in Nevada and California.

This cutworm has been recorded by Essig (24, p.682) as infesting carrots, but it is most injurious to corn and winter and spring wheat. It also attacks alfalfa, barley, beets, cabbage, flax, millet, oats, onions, potatoes, and rye. As weedy hosts it usually prefers dandelion and Russian thistle, but commonly injures tumbling mustard and native grasses as well.

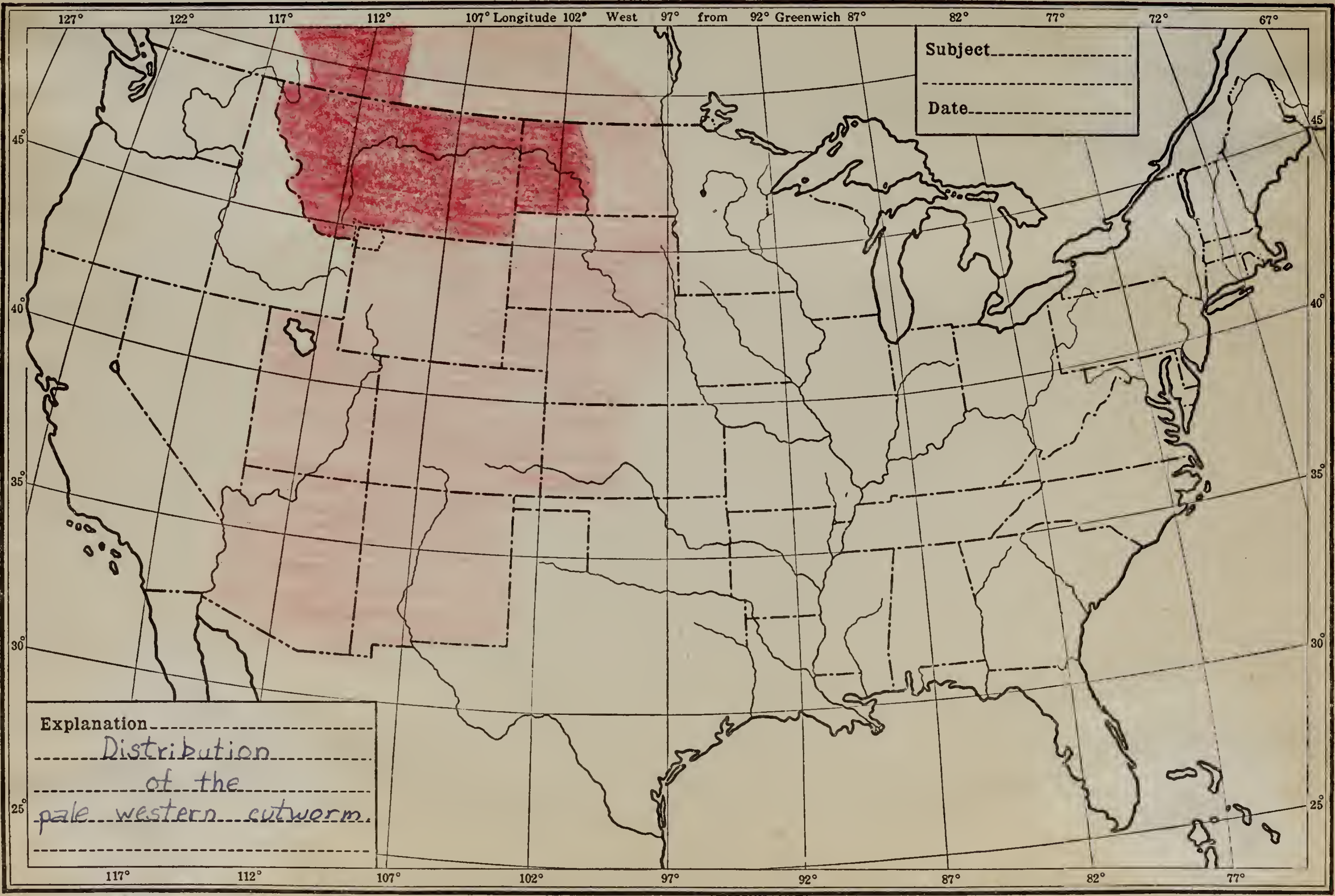
The wings of the moth are mottled with light and dark gray spots and wavy lines and measure one and one-half inches from tip to tip when expanded. The moths, which are both diurnal and nocturnal, emerge in late summer and lay their eggs in the soil. The winter is passed in the egg stage or perhaps occasionally as very young larvae in some regions.

The larvae are pale greenish gray with brown heads and conspicuous black spiracles. When mature they measure from one and one-quarter to nearly one and one-half inches long. They rapidly cut off one plant after another below the surface of the ground. Pupation occurs in the soil at a depth of two or three inches. Only one generation is produced each year.

Control. It is not as easy a matter to control

On the following page is a map which shows the distribution of the pale western cutworm. Intensity of shading indicates intensity of pale western cutworm populations.

McKinley's Geographical and Historical Outline Maps. No. 176b. The United States. (State boundaries.)



Explanation Distribution of the pale western cutworm.

Copyright, McKinley Publishing Co., Philadelphia, Pa.

Porosagrotis orthogonia as it is to control such other cutworms as Agrotis c-nigrum and A. unicolor. Since the pale western cutworm is an underground feeder, poisoned baits are generally ineffective. The insect is best controlled by thorough cultivation, planned crop rotation, and light traps.

A great deal of information concerning the pale western cutworm has been published. Bulletins by Webster and Ainslie (94, p.1-24) of the North Dakota Agricultural College and by Cook (15, p.1-79) of the University of Montana Agricultural Experiment Station are particularly useful. Both of these bulletins contain descriptions of each stage of the insect, accounts of its life cycle and natural enemies, and extensive discussions of control measures reinforced with experimental evidence.

Xylomyges eridania Cramer.

The semi-tropical army-worm (or southern army-worm)is found in Florida, usually, but has been observed as far north as South Carolina. It is a pest of celery in Florida and attacks castor beans, cotton, and several other crops.

The young caterpillars are yellow with black humps. As they mature, they gradually become darker, so that when full-grown they are black with narrow lighter lines. They attack young celery plants both in the seedbed and after they have been transplanted to the field. The arsenicals usually applied to young celery plants by commercial growers to destroy cabbage and celery loopers are also effective against the semi-tropical army-worm.

Arctiidae (tiger moths or woolly bears).

These moths are generally medium-sized and stout-bodied. They are often brightly colored and their wings are usually striped or spotted -- hence the name tiger moths. The caterpillars are popularly called woolly bears because they are covered with dense clusters of long hairs. Matheson (61, p.311) states that they feed on all kinds of herbaceous plants with hardly any choice of hosts. The small quantity of silk which they use in spinning their cocoons is liberally supplemented with larval hair.

More than two thousand species of Arctiidae are known. In spite of their general feeding habits, most of the group have not become serious pests. The one species which has been recorded as attacking Umbelliferae has been described as omnivorous.

Diacrisia virginica (Fabricius)[10]

The caterpillars of this species are known as yellow bears or yellow woolly bears. The moths are commonly called Virginia tiger moths or white ermine moths. They are common

---

[10] Often placed in genus Spilosoma.

throughout the United States and include carrot, celery, and parsnip among their numerous host plants. Other plants of economic importance upon which the yellow bear feeds are:

alfalfa
asparagus
bean
beet
blackberry
cabbage
cauliflower
cherry
clover
corn
cotton
currant
eggplant
gooseberry
grape
melon
pea
peanut
potato
pumpkin
radish
raspberry
rhubarb
squash
sweet potato
turnip

Diacrisia virginica may be found in flower gardens and in greenhouses on:

calendula
calla
canna
chrysanthemum
colleus
dahlia
fuchsia
hollyhock
hyacinth
lily
marigold
moonflower
morning glory
petunia
salvia
snapdragon
sunflower
verbena
violet

It feeds also upon the birch and the butternut and upon the following weeds:

dock
lambsquarters
pigweed
ragweed
Russian thistle
Spanish needle

The Virginia tiger moth is snowy-white with yellowish brown abdomen and black spots located dorsally, laterally, and on the wings. Its wing expanse varies from thirty-eight to fifty millimeters (one and one-half to one and three-quarters inches). The eggs are laid on the foliage, which the larvae attack upon hatching.

The color of the caterpillar's body varies from pale

yellow to dark brown. The dense long hairs covering it are most often yellow or straw-colored, as the name implies. Their color varies considerably, for in various specimens they may be white, brownish-yellow, light brown, or fox-red. At maturity the larvae measure from forty to fifty millimeters long (about two inches). They are most abundant in July and August, but rarely numerous enough to cause serious damage.

The larvae spin tough oval cocoons of silk and body hair under loose shelters. Members of the second brood hibernate thus, as many as twenty or thirty cocoons sometimes being found under the same shelter.

At least three hymenopterous parasites help keep the yellow bears from increasing unduly. Two belong to the Ichneumonidae. They are Ophion bilineatus Say and Ephialtes sanguinipes" (Cresson). The third, Dibrachys diacrisiae (Crawford), belongs to the Pteromalidae.

Handpicking these conspicuous yellow bears is generally sufficient to control them. In addition, it is often possible to kill large numbers of their clustered hibernating cocoons at one time. If these caterpillars become abundant they may be killed by dusting or spraying the plants with arsenate of lead. O'Kane (66, p. 182) suggests a heavy dose of

---

"Often incorrectly spelled sanguineipes, and sometimes described as Pimpla erythropus Vier.

Paris green and lime, as he says the caterpillars are resistant to poisons.

Papilionidae (the swallowtails).

The Papilionidae is a group of large butterflies, instantly recognized by the finger-like lobe or tail which projects backward from the posterior margin of each hindwing.

In spite of the fact that members of this group may be seen almost everywhere, they seem rarely to become pests. It is rather the beauty of many of the adults and the striking appearance and habits of the caterpillars which have attracted to them the attention of entomologists and others as well.

One species which is intimately associated with umbelliferous crops and weeds is now considered in some detail.

Papilio polyxenes Fabricius.

The black swallowtail butterfly, Papilio polyxenes Fabricius, is called the celery worm in its larval stage. It is also known as Papilio ajax Linnaeus and P. asterias. A species with the same habits, which replaces P. polyxenes

west of the Rocky Mountains is *P. zelicaon* Lucas , the western parsley caterpillar. It has been termed also by various authors *P.zolicaon* Bdv., *P. californica* Men., and *P.coloro* Wright.

Papilio polyxenes is common in the southern parts of Canada and in the United States east of the Rocky Mountains. It is commonly reported from New England, the Atlantic States, and the Mississippi Valley. Scudder (80, p.137) states that it extends throughout Florida and is also found in Cuba, Haiti, and San Domingo, as well as in Mexico and a considerable part of Central America. Lutz (60, p.141) describes its range as extending south to Peru. A closely allied short-tailed species occurs from the Gulf of St. Lawrence through Anticosti Island and Newfoundland into southern Labrador. The western species, *P. zelicaon,* occurs commonly in the lowlands from the Pacific Coast to the Rocky Mountains.

The plants attacked by the celery worm are such *Umbelliferae* as carrot, celery, parsley, parsnip, caraway, and dill. In some sections of California the larvae also feed on the foliage and young fruit of orange trees, but are

never sufficiently abundant to be serious. Common native hosts are wild carrot, wild parsnip, rue, poison hemlock (Conium), water hemlock (Cicuta), dog fennel, and sweet fennel (Foeniculum vulgare (L.) Gaerth), also called sweet anise or wild anise.[12]

The wingspread of the black swallowtail butterfly is between three and four inches. Both pairs of wings are black, crossed up and down by two rows of yellow spots and by a row of narrow marginal crescents of the same color. In the outer of the two rows of yellow spots first mentioned, the markings are round on the forewings and lunate on the hindwings. The two rows of spots are much more distinct in the male than in the female, the inner row on the hindwing of the male forming a yellow band unbroken except by black lines on the veins.

Between the two rows of yellow spots on the hindwings is a blue shading, more conspicuous in the female. The anal angle of the hindwings bears a red or orange spot with a black center. On the under surface of the wings the markings are similar, but the yellow becomes orange or orange-red. Medially, from the posterior margin of the hindwing there projects the finger-like "tail".

---

[12] The term anise is incorrectly applied to F. vulgare (L.) Gaerth.

The antennae are club-shaped and bear dorsally at their base two yellow spots. The palpi are edged within with yellow. A bright yellow spot appears on the anterior edge of each side of the thorax. The abdomen is oval.

In flight the black swallowtail butterflies flit first one way then another over the fields, often coming back to a spot just visited. Generally they fly not over a foot above the ground or plants. Scudder (80, p.127) strikingly relates their behavior when frightened:

> When alarmed, however, they go at great speed, zigzagging rapidly with occasional upward and downward starts thrown in, kept up even when the pursuer or the moving object which caused the fright may be far in the rear.

The butterflies are greatly attracted to flowers and are valuable in their pollination. The United States Department of Agriculture claims that they actually injure the verbena by their continual visits, as in withdrawing the proboscis they pull the flower to pieces.

Teale (87, p.184) notes the curious fact that in certain rolling sections of the country the males predominate on the hilltops and the females in the valleys.

In the south the butterflies winter over, but in the north this period is spent as the pupa. More detailed statistics on the life histories in both areas will be given after the descriptions of the other stages have been completed.

The eggs are laid singly on the upper (rarely on the

under) surfaces of the finely cut leaves of umbelliferous plants, Never more than one is laid on a leaflet, though eggs have been found on closely adjoining leaflets. Usually they are attached to the central vein or to one of the side veins. After the female has softly alighted on the end of a leaflet she clings to it for a moment, then curving her abdomen forward deposits a single egg and flies away to another leaf.

The eggs are smooth, spherical globules, without markings, about one millimeter in diameter. They vary from creamy white to honey yellow in color at first, as they mature changing to a reddish brown color in parts. Essig (24,p.634) describes the eggs of the western species as being bluish white in color. The time spent in the egg, says Scudder (80, p.132-133), varies from ten days in the north to eight or nine days in the south. In the extreme south the egg stage may be shortened to only five days. Fernald and Shepard (27,p.294) record the egg stage as consuming ten days, but Munro and Riddle (65, p.58), workers at the North Dakota Agricultural Experiment Station, report that the eggs hatch in the course of a week.

For the first three or four stages the tiny larva is angular and covered with spiny warts in longitudinal rows. It is of a black color, banded with white over one and a portion of a second of the central abdominal segments. In addition there is a white band at the caudal end and the rest of the

body is checkered with tiny white spots. Essig (24,p.634), in speaking of the western species, asserts that the larvae are almost wholly black, with a yellow blotch near the middle dorsum and many lateral and dorsal orange spots near the bases of the spines.

Usually at the next to the last molt the larva loses its black and white spiny covering. The mature larva is a smooth, naked, cylindrical bright green caterpillar. Each segment bears a velvety black crossband which may enclose six yellow or orange spots or may fail to close these in on the anterior side of the band. The yellow or orange spots are arranged in longitudinal series. Essig (24, p.635) describes the black bands around the body in the western species as being alternately continuous and broken.

The length when mature is recorded by Fernald and Shepard (27, p.284) as about two inches, and by Gilbert and Popenoe (39, p.21) as about one and one-half inches. Like all lepidopterous larvae the growth is extraordinary during warm weather. They eat voraciously in their last stage. They increase their weight tenfold in the same time.

The celery worm has prominent defensive scent organs called osmeteria.[13] Just posterior to the head, on the

---

[13] Often found spelled osmateria.

prothoracic segment, is an opening out of which a soft, fleshy, Y-shaped tentacle can be protruded. This widely-forked horn is brilliant yellow or orange. When the insect is touched or threatened, often with little incitement it thrusts out these horns, but rarely to their full length. The organ gives off a pungent, disagreeable scent, sometimes portrayed as sickening or resembling the odor of bruised parsley leaves. Although the osmeteria are ineffective against branconid wasps, they are probably useful against larger enemies like birds. They are quickly withdrawn again when the endangering influence has disappeared.

Teale (87, p 192) describes a caterpillar "battle" between two of these celery worm larvae which was witnessed by A. B. Comstock:

> They were marching along the same slender stem and actually collided before they became aware of each other's presence. Then they did a surprising thing. They drew back and butted each other like billy goats. Three or four times they collided with an audible thump. Then they turned tail and fled in opposite directions along the stem.

The bright colors of the caterpillars make them very conspicuous objects, the more so as they live fully exposed on the upper surface of the leaves of their food plants and feed in plain view. The far northern species, found in Newfoundland, has adapted itself to the climate. The larvae hide among the leaves during cool nights, and at noonday sun themselves on rocks and gravel beds to get thoroughly warmed.

Its simple eyes and minute antennae make it necessary for the celery worm to search for food by lifting its body and swinging it back and forth. It feeds upon the foliage, stripping the leaves clean as it goes. It may occasionally cause severe injury to young plants, but generally it is the showy colors that make its appearance known rather than the injury it does.

The constant voracious feeding continues throughout larval life except during the molting periods. The larva rests for a short period, then when ready to molt, especially in the later stages, climbs to the outermost leaves of the plant to gain the fullest exposure, probably to avoid the friction of nearby moving leaves against its soft new skin. Observations made by Duncan and Pickwell (22, p.57) showed that the exoskeleton was never eaten, as it is by certain other lepidopterous insects such as the monarch butterfly.[14]

Metcalf and Flint (63, p.510), Scudder (80, p.132) speaking of southern United States, and Munro and Riddle speaking of North Dakota all say that the length of the larval life is approximately one month. Fernald and Shepard (27, p.284) give this time as from ten days to several weeks, and Duncan and Pickwell (22, p.59) report that in one definite record it took seventeen days for a larva to mature.

---

[14] Danaus plexippus Linnaeus, Family Danaidae.

When preparing to pupate the caterpillar crawls away to a fence or the side of a house or to the underside of a twig or other solid support. It commences by spinning a small mat of silk in which it securely fastens its anal prolegs. It then extends the silken bed anteriorly a little. Next, a strong belt of silk is spun in back of the pupa at about the mid-region of its body and is attached to the support on both sides. This enables it to lean back like a lineman on a telephone pole. Duncan and Pickwell (22, p.60) describe the construction of the girdle in detail:

> In spinning the girdle the larva reaches back to a point just at the side of the first pair of abdominal prolegs for the attachment. With the silk thread apparently held between the first and second pairs of thoracic legs, the larva swings back and away from the stem until the anterior part of the body, including the first pair of abdominal prolegs, is nearly at right angles to the stem. It continues in an arc and swings up to the opposite side of the stem and there makes a second attachment.
>
> To make an attachment the larva works its head back and forth for some seconds as if it were pasting. Then it starts the arc back, out, and to the other side. As it progresses along the thread, it moves the head back and forth through short distances, but farther in one direction than in the other, thus maintaining the general body movement.
>
> Observation shows that the time occupied in working over the entire arc from one side to the other, is two minutes. Some thirty loops, back and forth, are made. The thread increases visibly in size as the larva works. When the process of girdle making is completed the larva pulls its head back to the thoracic legs and against the stem, and then straightens out.

The cord passes behind the larva between the second and third abdominal segments. Observations have shown that the construction of the girdle consumes the greater part of an hour. It takes about twenty-four hours between the first signs of pupation and the completion of the girdle. The time between the completion of the girdle and the actual pupation is given by Scudder (80, p.136) as twenty-four hours and by Duncan and Pickwell (22, p.61) as thirty-six hours. During this time the cord sinks so far into the soft skin that it becomes completely surrounded by it.

The exoskeleton of the suspended larva, which is now called the prepupa, shows signs of the approaching molt by losing its luster and becoming corrugated. The fissure occurs dorsally, just posterior to the head, and the larval skin is quickly drawn toward the posterior end of the body by a succession of contractions. Before the larval covering is entirely discarded a structure called a cremaster, covered with minute hooks and attached to the tip of the pupal abdomen, is drawn out of the posterior end of the larval skin and inserted into the surrounding silk pad. Then the larval skin drops away from the pupa completely.

The angular pupa closely resembles the chrysalis of the cabbage worm.[15] It varies considerably in color from

---

[15] Pieris rapae Linnaeus, Family Pieridae.

yellowish green to pale green through shades of gray, buff, and pale brown to dark brown. Scudder (80, p. 136) describes its color as wood-brown more or less tinged with greenish and streaked with black. Its surface is rough and ragged-looking, especially anteriorly, reminding one of a piece of rough bark. There is a protuberance dorsally on the thorax, amd an ear-like or eye-like projection on each side of the head, which Folsom (28, p. 168) claims suggests an ancestral active condition of the pupa.

Much information exists concerning the length of the pupal stage, twelve to fifteen days being most commonly reported. The period has been stated to be as short as eight days and as long as eighteen days.

Just before the adult is ready to emerge, the black and yellow pattern of the wings becomes noticeable through the pupal wing pads, and the wrinkles between the segments of the abdomen become more prominent. Within a few hours the exoskeleton of the pupa splits open and the adult comes forth. The fissure appears all around the head and extends back over the outer borders of the wing pads. The fissures do not quite meet posteriorly, so that there is formed a lid, which the adult must raise in escaping and which afterwards falls again, closing the empty chamber. The adult crawls to the surface to which the chrysalis is attached and the wings at once start to unfold. Their expansion is induced by the forcing of blood into them from the abdomen, which subsequently becomes

reduced in size. Concurrently with this period of wing expansion and contributing to the diminution of the abdomen, a large amount of milky fluid is ejected from the anus. The whole process of expansion is accomplished in about ten minutes, its termination being marked by the straightening out of the "tails" on the hindwings.

The maxillae develop apart in the pupa, and it is necessary for the adult to spend some time curling and uncurling them to get them firmly interlocked to form the proboscis. Although, as has been stated, the wings expand so rapidly, they do not become hard enough to permit flight for an hour or more.

The celery worm has two generations a year in the north and at least three in the south. In the north the winter is spent as a chrysalis. The butterflies are usually first noticed about the twenty-first of May, sometimes earlier, but rarely before the fifteenth. Sometimes their appearance is delayed until the last of May, and in the latitude of northern New England and at corresponding altitudes they may not be seen until as late as the last week in June. The butterflies of this brood may not be observed until early in July or later in July in the far north, and eggs are found throughout this period.

The larvae which hatch from these eggs become mature and pupate between the tenth of July and the end of August.

The second generation adults emerge from late July to September. Members of this brood may be found in flight at least until the middle of September, the females laying their eggs throughout August. The full-grown caterpillars from these are active from the last of August until the approach of October. It is the chrysalids formed by these which hibernate.

In the south the winter is passed as adults. Females oviposit from the middle of March until nearly the end of April. The generation which hibernated has all disappeared before the first of May, by which time the new first generation adults have begun to emerge. The second generation generally emerges in the latter part of July. The adults of the third generation begin to appear before the middle of September but some of them do not emerge until the end of October. It is these third generation adults which hibernate.

Control. Common as is the celery worm on umbelliferous plants, it seldom causes enough damage to warrant any control. Three hymenopterous parasites aid in reducing its numbers. One, and perhaps most important, is a braconid, Apanteles lunatus (Packard). Another is a chalcid, Brachymeria ovata (Say),[16] and Trogus exesorius Brullé, Family Ichneumonidae, is the third.

---

[16] Also known as Chalcis annulipes Walker and C.incerta Cress.

Handpicking is usually sufficient to control the celery worm when it becomes a pest, and is easily accomplished by knocking them from the leaves and crushing them. Dusting with arsenate of lead or calcium arsenate has been recommended. White and Doolittle (100, p.7,25) give the following directions for the control of the celery worm on carrots with calcium arsenate:

> Calcium arsenate---------------1 pound
> Hydrated lime------------------2-3 pounds
> Place the materials in a tight can or similar container. Add several stones one inch in diameter to aid mixing process. Place tightly fitting cover on can. Shake or rotate can for five minutes. Remove stones by passing mixture through sifter or screen.

Essig and Hoskins (25, p.37),writing for the California Agricultural Extension Service,advise spraying with a mixture of three pounds of powdered basic arsenate of lead to one hundred gallons of water to which a spreader has been added. They state that both standard and basic lead arsenate come also in paste forms which contain only about half as much arsenic as the powders and hence should be used at double the amounts stated. They caution that spraying celery with poisons is a dangerous procedure which should be done only with the advice of experts.

Munro and Riddle (65, p.42,58) advise dusting the plants with one part of Paris green mixed with seven parts of air slaked lime or flour. The application should be made when the plants are moist with dew,since the poison adheres better

then. No poison toxic to humans, of course, should be used on crops within three weeks of when they are ready to be marketed. Fernald and Shepard (27, p.295) claim that derris would be entirely satisfactory if control were necessary.

CHAPTER IV -- DIPTERA.

Flies in general are small insects; many are nearly microscopic. Their most characteristic feature is the presence of only one pair of wings -- the forewings. The hindwings are represented by a small pair of slender, knobbed stalks called halteres. The head and thorax are connected by a short neck which makes possible considerable rotation of the head.

Very large compound eyes cover the greater part of the surface of the head. Many species bear three ocelli between or behind the eyes. The mouthparts typically are fitted for sucking or for piercing and sucking.

The larvae of flies are called maggots. They lack true legs and may possess no distinct head. Some construct cocoons when full-grown, but others pupate within the last larval skin, which is known as a puparium.

Two families in this order each contain a species which shows a decided preference for the Carrot Family. One of these species is an extremely serious pest of commercial carrot plantings. A third family contains a species, which, although almost wholly a pest of crucifers, according to one report damages celery to a slight extent.

Anthomyiidae.

The members of this family are common everywhere, but relatively little has been learned about them. They are small to medium-sized drab flies which are somewhat similar to the housefly in appearance. In fact, there have been and still are many entomologists who include this family with the Muscidae. On the other hand, Comstock (12, p. 863) states that the Anthomyiidae are structurally distinct from the Muscidae. In any case, those who consider it a separate family do not agree upon which genera it should include.

The adults may be seen resting on leaves or flowers and often gain entrance to our homes and buildings. The Anthomyiidae is the only one of the three dipterous families under consideration that possesses oral vibrissae.[1] Its members have fairly large squamae (a pair of lobes near the base of each wing which fold beneath it when it is closed).

The habits of the larvae are varied. Many are miners or borers in plants. Others are scavengers and some are predacious. A detailed description of anthomyiid maggots is given by Imms (54, p. 649). He states that they have twelve segments in addition to the head and the segment-like section just behind the head. They are cylindrical in form, tapering anteriorly. The blunt end bears a border of a variable

---

[1] Curved bristles situated just above the mouth.

number of short fleshy tubercles. The tracheal system is amphipneustic.

The cephalic spiracles have from six to thirteen lobes, while the anal spiracles have three small radially arranged slits. Beginning usually with the fifth segment, locomotory protuberances ringed with tiny spines may be seen.

A number of the five hundred species of Anthomyiidae recorded from North America are injurious. The following species, which generally confines its attacks to cruciferous plants, is said by one observer to have caused slight damage to celery.

Hylemyia brassicae (Bouché).[2]

This species has also been listed under the generic names of Phorbia, Pegomyia, Anthomyia, Aricia, and Chortophila. Under one or more of these genera the following specific names have been employed: brassicae, floralis, floccosa, raphani, and radicum. An account of this synonymy, accompanied by a bibliography, is given by Schoene (79, p. 103-104). Among the more popular common names of this insect are cabbage maggot, cabbage root maggot, radish maggot, and western radish maggot.

The cabbage maggot has been known in Europe since 1833. Several records of its injury in Germany, Switzerland, and

---

[2] The generic name is sometimes spelled Hylemya.

the Netherlands exist, but it has received most attention by the economic writers of Norway, Sweden, Finland, and Great Britain.

The insect was first recorded in the United States in Massachusetts in 1835. Since then it has been frequently reported as occurring in destructive numbers there. In the trucking regions near Boston it has made it very difficult in some seasons to grow early cabbage. It now occurs from Minnesota eastward, probably doing the greatest damage in the northeastern states.

To the west it has been reported from North Dakota, Montana, Idaho, Washington, Oregon, California, and Colorado. Although it occurs even in the Gulf States, it is seldom serious south of the latitude of southern Pennsylvania (forty degrees north latitude).

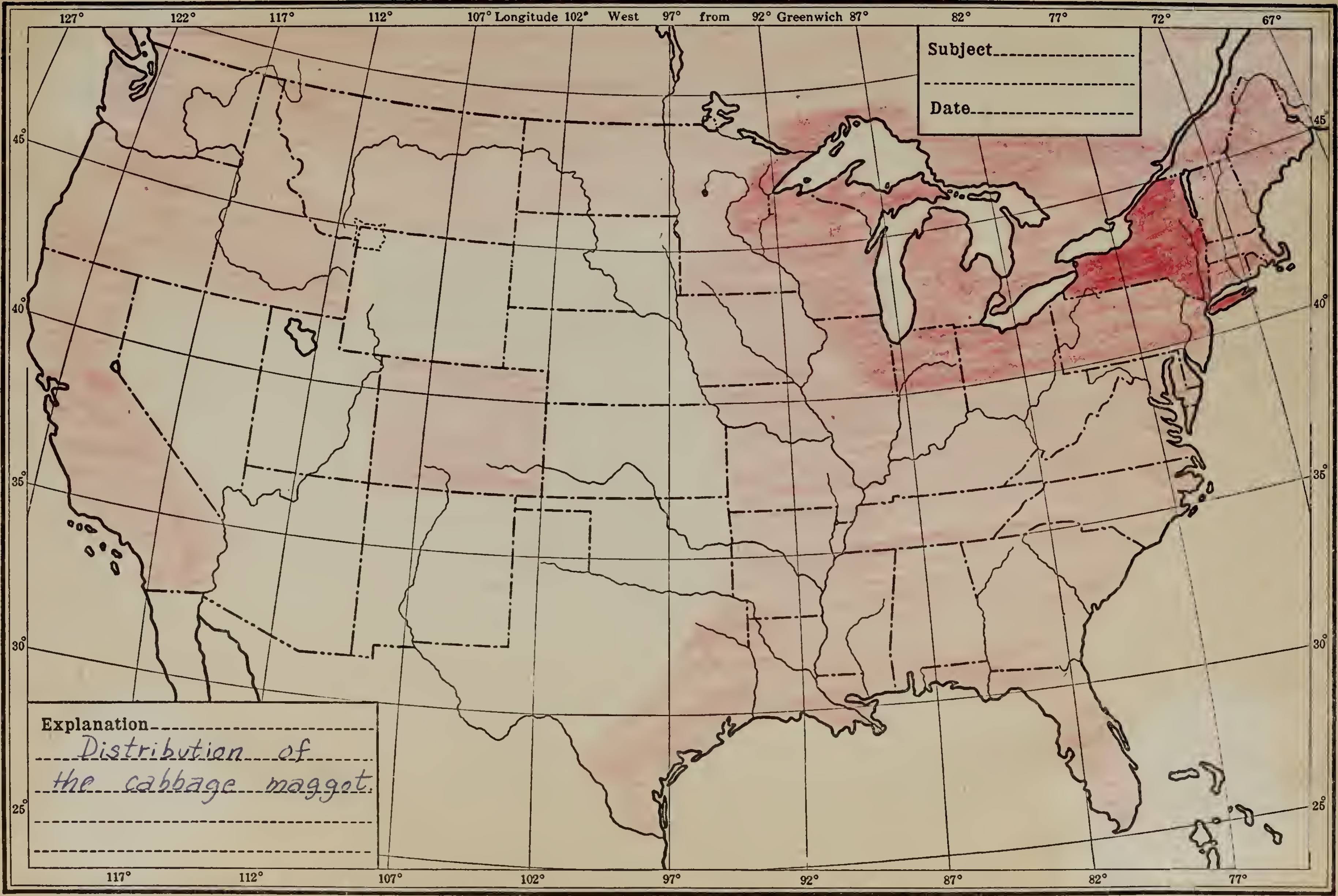
The entomological literature of the Dominion of Canada in reference to this species is particularly abundant. As early as 1885 serious injury in all parts of Canada, from Nova Scotia to Vancouver Island, has been reported. It is said to be the only important insect pest at Sitka, Alaska.

The cabbage maggot varies greatly in numbers from year to year. Frequently damages by the pest are unequally distributed within the same community.

The more important host plants of the cabbage maggot are broccoli, brussels sprouts, cabbage, cauliflower, kale,

On the following page is a map which shows the distribution of the cabbage maggot. Intensity of coloration indicates intensity of cabbage maggot populations.

McKinley's Geographical and Historical Outline Maps. No. 176b. The United States. (State boundaries.)



Subject

Date

Explanation

Distribution of
the cabbage maggot.

Copyright, McKinley Publishing Co., Philadelphia, Pa.

radish , rape, rutabaga, and turnip. It may cause slight infestations on beet, celery, and cress, and will attack the roots of various cruciferous weeds.

The adult flies resemble the common house fly, but are only about one-half as long (one-fourth or one-fifth of an inch—five millimeters). They are pale gray or dark ashy gray, with black, longitudinal thoracic stripes and numerous black bristles covering the body. They have clear wings.

The white, legless and headless maggots fit the family description given above. They feed in the bases of the roots and in the crowns of the plants, often causing them to wilt and die suddenly. Replacement of young plants which become infested is almost always necessary. Metcalf and Flint (63, p. 506) state that frequently from forty to eighty percent of the crops are destroyed, causing thousands of dollars' loss annually in many states.

Generally the winter is passed as pupae in the soil, but in some regions the adult flies hibernate. Each year from two to four broods are produced, depending not only upon the latitude, but also upon seasonal variations in weather. Hot, dry weather slows down feeding by hardening the roots upon which the maggots feed and by lengthening the pupal stage.

Natural enemies of the cabbage maggot are said to exist in the east, but they do not provide an effective control. Clean culture, rotation of crops, deep fall plowing, and abundant fertilization reduce the maggot population somewhat.

Screening and tarred paper disks have met with success in preventing the females from laying eggs near the crops. Where it is possible, growing cruciferous plants in the winter months and planting radishes early help to avoid infestation.

Where the insect has become at all firmly established, the use of insecticides is almost inevitable if crop destruction is to be prevented. It has been found beneficial to coat seeds with calomel and to dust the stems of seedlings with a calomel and cornstarch mixture at transplanting. Calomel may also be poured about the bases of plants in water suspension or applied as a dust in the same way. Similar treatments with corrosive sublimate solutions and carbolic acid emulsions have given good results. Carbon disulfide, poured into holes in the soil near plants has been recommended, but proves too expensive for commercial use.

Of the quantities of literature written upon the biology and control of the cabbage maggot, the following references will be found particularly helpful (each is listed by its bibliographical number in this paper):
(79), (69), (40), (10, p.8-14), (17, p.6-11), (53), (38), (1, p.41-66), and (88).

Trypetidae (fruit flies).

The Trypetidae are small flies with wings which are usually mosaics of flowing dark markings and clear areas. The females are equipped with a conspicuous, harny, three-jointed ovipositor. Oral vibrissae are absent or vestigial.

Fruit fly maggots are cylindrical or barrel-shaped when fully grown. At the anal end are a pair of rounded tubercles and the posterior spiracles, which consist of three pairs of small slits. The cephalic spiracles are many lobed, with from fourteen to thirty-eight processes each.

The larvae attack plants in a variety of ways. Some feed on the flowers, seeds, or fruits. Others mine in the leaves or bore in the stems. Still others form galls on the stems or roots.

The Trypetidae is a large family, and many of its members are serious agricultural pests. The species of greatest importance are those which attack and often completely ruin our important fruits. One species, which as yet has attracted little attention, bears watching because of its preference for the Umbelliferae.

Acidia fratria (Loew).

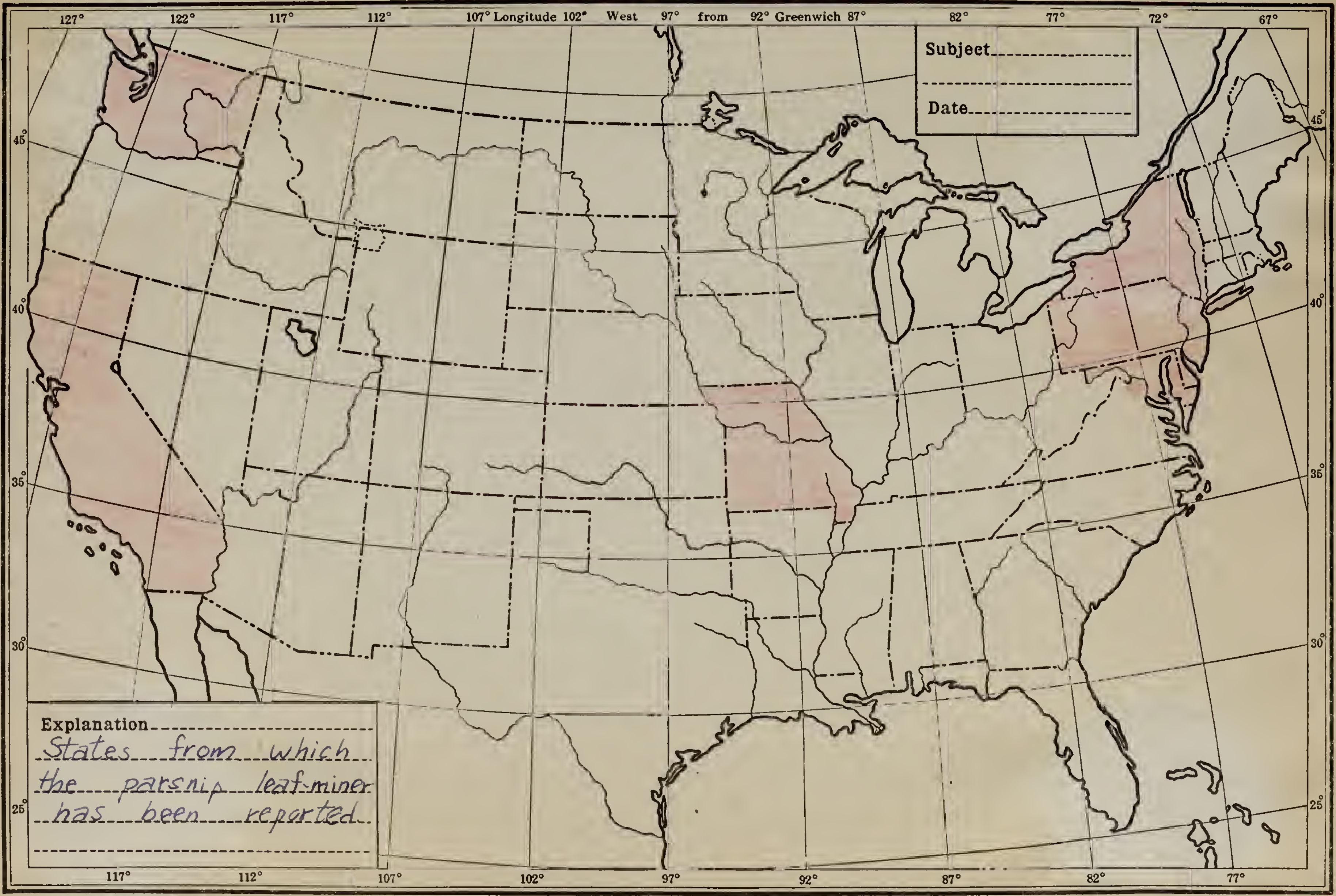
Acidia fratria (Loew), the parsnip leaf-miner, was formerly known to many entomologists as Trypeta fratria. It is identical with Trypeta liogaster Thomson. It is probably identical with Acidia (Trypeta) heraclei Linnaeus, a European species known especially for its damage to celery in England. There it is commonly called the celery fly or celery leaf-miner. Frost (36, p.182) considers that A. heraclei is merely a darker variety of A. fratria and that the difference between the two results from the relative amount of moisture at the time of emergence. He has discovered that adults which transform in wet weather are often darker in color than adults which transform in dry weather.

Reports on the distribution of the parsnip leaf-miner are comparatively few, but indicate a rather wide range. Before 1900 it had been reported from the "Atlantic States", New Jersey, Missouri, California, and the State of Washington. Beginning in 1903, and continuing for several years, it caused damage to parsnip leaves in the District of Columbia. The scarcity of subsequent data on its distribution and the fact that it has attracted relatively little attention among entomologists show that its numbers have not increased to any extent. The parsnip leaf-miner has also been found on wild parsnip.

The body of the adult fly is some shade of yellow, usually pale yellow or clay yellow. The head and legs are yellow, and

On the following page is a map which shows in color the states from which the parsnip leaf-miner has been reported.

McKinley's Geographical and Historical Outline Maps. No. 176b. The United States. (State boundaries.)



Subject

Date

Explanation States from which the parsnip leaf-miner has been reported

Copyright, McKinley Publishing Co., Philadelphia, Pa.

the ovipositor, while often yellow also, may be much darker, sometimes even black. The abdomen is pale green or greenish, and the large eyes are brilliant green with bluish reflections.

The fly is five millimeters (three-sixteenths of an inch) long and has a wingspread of eleven millimeters (seven-sixteenths of an inch). The wings are handsomely decorated by flowing yellow or yellow-brown markings alternating with clear areas. Near the middle of the anterior margin of each wing is a dark gray spot. In a relative position on the posterior margin of each wing is a larger, lighter gray spot.

So far as has been determined, there are no accounts of egg-laying or of the eggs of Acidia fratria. The location and direction of the mines in the leaves have led observers to believe that the eggs are deposited near the margin of the leaf and toward the apex. The mines almost always extend to the margin of the leaf, and the mature larvae are generally to be found near the junction of the blade with the petiole.

The maggots are about seven millimeters (one-quarter of an inch) long and approximately one-fifth as wide. They are almost transparent but the pale yellow of the internal structures is visible. The greenish contents of the alimentary tract are apparent in the abdominal area. The anal segments bear a four-lobed knob on which are located three pairs of spiracles.

The mines of Acidia fratria are not typical.

Most leaf-miners leave clear cut trails of withered tissue across the leaf, with healthy tissue intervening. The entire infested portions of the leaf in which the mines of Acidia fratria are located merely wither and dry up. The larvae can be located within the mines by holding the leaf to the light. The maggots usually feed closely together, and it is common to find two or three of them in the same mine. As many as eight have been observed in a single leaf. They feed in between the two outer surfaces of the leaf, leaving behind them a very fine, dry, almost black excrement which can also be seen by holding the leaf to the light.

The mines are of various sizes, some being only about five-eighths of an inch in diameter, while others cover most of the leaf. They are irregular in form, usually roughly cylindrical, but near the apex of the leaf more often with three unequal sides. The mines are not often found in the older, lower leaves and plants grown in the shade have been found to be most heavily infested.

The only record encountered stating the amount of damage done by the parsnip leaf-miner concerns the attacks at Washington, D. C. in the early nineteen hundreds. Chittenden (6, p.9) writes that by July sometimes twenty-five percent of the leaves were destroyed.

At maturity the larvae shorten and harden, forming puparia. Often several puparia are found in a group, usually in the old larval mines. In some cases, particularly when the larval mines are small, the larvae seek a fresh portion of the leaf or another leaf in which to pupate. Soon the withering leaf exposes the first two or three segments of the puparium. Upon further drying of the leaf, the whole puparium may protrude, revealing its attachment to the under surface of the leaf. It is held there by a thick secretion.

The puparium is elliptical in outline, tapering, although not sharply, at both ends. It is flattened ventrally and consists of eleven well-defined segments. It measures four and one-half millimeters (one-fifth of an inch) long and about half as wide. At first it is light green in color but later assumes a straw-colored hue. Microscopic spiracles are arranged in two arcs on the most anterior segment. Each arc makes up about one-third of a circle and is composed of from twenty-one to twenty-four spiracles.

The parsnip leaf-miner has at least two broods each year. From the scanty data available it seems that in the vicinity of Washington, D. C. one brood pupates around the twenty-second of May. The adults emerge in about two weeks and produce a brood which pupates soon after the middle of July. Adults emerge from these puparia in August.

Control. One parasite, a chalcid belonging to the genus

Syntomosphyrum, has been reared from the parsnip leaf-miner maggot.

Crops of celery and parsnip should not be allowed to go to seed, for plants that have run to seed are preferred by Acidia fratria. Various control measures have been successfully employed in Europe, where this insect is more of a problem. A mixture of finely powdered soot, three parts, and lime, one part, dusted upon the leaves is said to prevent oviposition. Chittenden (6, p.13) believes that other repellents, such as road dust, would duplicate this effect. Sprays of kerosene emulsion and of carbolized kerosene emulsion are claimed to protect young plants by their repellent action. It is questionable whether these liquids would penetrate the leaves enough to be successful except when the larvae were mature and the walls of their mines were thin. By then, of course, it would be too late to lessen the amount of damage done by that brood.

Psilidae.

The adults are small, slender, and dark flies with rather long legs and antennae. The slender abdomen is more than twice as long as the thorax. Oral vibrissae are absent.

The Psilidae is a small family, with only about thirty-five known members in North America. One species is a dangerous enemy of carrots and celery.

Psila rosae (Fabricius).

The carrot rust fly, Psila rosae, was first described as Musca rosae by Fabricius in 1794. Fabricius later changed it to Tephritis rosae in 1805, and before the middle of the nineteenth century other writers had assigned it to the genus Psilomyia and to the genus Scatophaga. Since 1800 it has come to be known everywhere as Psila rosae.

The carrot rust fly is a native of central Europe and is now prevalent in northeastern United States and eastern Canada, the north central states, and the Pacific northwest. Fabricius asserted that the original habitat of Psila rosae was Kilia, in Bessarabia, a province in what was formerly southwestern Russia and is now under the rule of Rumania. Before the last decade of the nineteenth century it had become well established in Great Britain and Germany. An infestation was reported in 1931 at Auckland, New Zealand, and although no effort has been made to determine its presence in Africa, Asia, or South America, it is suspected to be present in those regions of these continents where the climatic conditions are similar to those favoring it in North America and Europe.

Psila rosae was first identified in North America at Ottawa in 1885 by Dr. James Fletcher, Dominion Entomologist of Canada. Although considerable damage occurred there the following year, and also at Quebec and Montreal, no serious injury was again reported until 1895, when another outbreak, which lasted

several years, was reported. By the end of the century the pest had become firmly settled in Quebec, Ontario, and New Brunswick, and serious losses were again reported throughout eastern Canada during an extensive attack in 1928 to 1930.

The carrot rust fly was first recorded in the United States in April, 1893 by Professor F. L. Harvey of the Maine State College as occurring at Pittsfield, Somerset County, Maine. Only once since, in 1928 and 1929, has it occurred in sufficient abundance in Maine to cause important crop loss. The first flies in Massachusetts[3] were grown from maggots found in carrots near Haggett's Pond, Andover. In this state the pest became extremely widespread and numerous between 1926 and 1930, but since that time its numbers have diminished remarkably. In New Hampshire some crop damage to carrots has occurred. Its troublesomeness has not become very evident, however, probably because carrots are not an important crop there. Since 1923 a certain amount of crop loss has been reported from Rhode Island, but the damage there does not approach that done in Massachusetts. It is not considered an important pest in Connecticut and has rarely been found in Vermont.

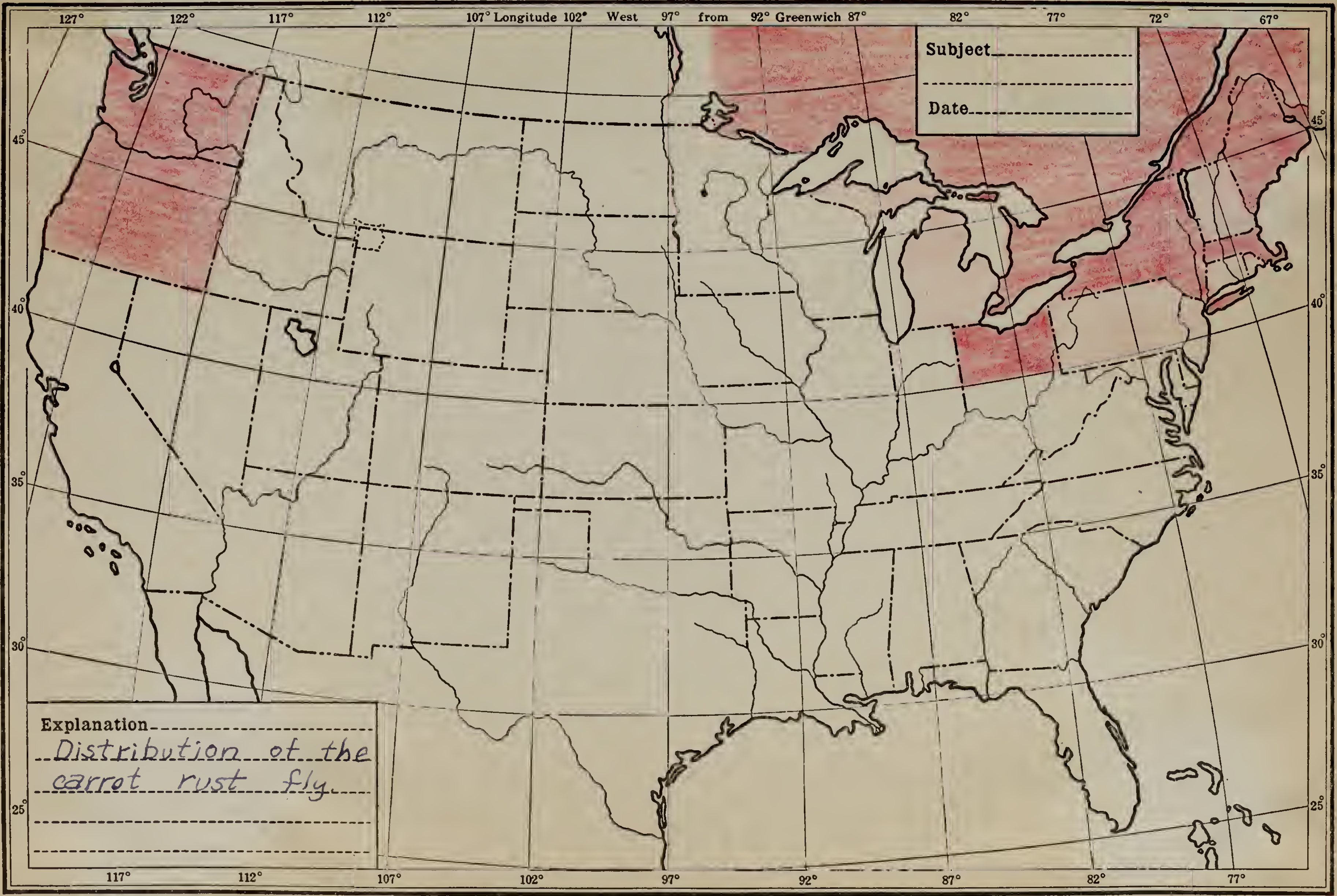
In northeastern United States the carrot rust fly is troublesome not only in New England but also in Pennsylvania, New Jersey, and New York. It is the most serious insect enemy of carrots in New York, having caused serious damage there since 1901. Infestation in New Jersey and Pennsylvania has

---

[3] Now at the Boston Museum of Natural History.

On the following page is a map which shows the distribution of the carrot rust fly. Intensity of shading indicates intensity of carrot rust fly populations.

McKinley's Geographical and Historical Outline Maps. No. 176b. The United States. (State boundaries.)



Explanation

Distribution of the carrot rust fly.

Copyright, McKinley Publishing Co., Philadelphia, Pa.

been slight, but the outbreak in Adams County and Fulton County in the latter state are important in that they represent the most southerly limits known for the rust fly.

Of the north central states, Ohio has been hardest hit, the damage in Michigan being slight and remaining quite localized. Entomologists in Illinois, Indiana, and Wisconsin have been on the watch for the insect, but so far it has not invaded their territory.

In the northwest, first specimens were taken in Washington in 1908, and starting in 1929 carrot crops have suffered from it more and more each year. It has not been found to the north in western Canada, but has spread southward into Oregon, where it has been reported as of economic importance. Only museum specimens have been recorded from Idaho and Colorado.

The most common host plants of the carrot rust fly are carrot, celery, parsley, and parsnip.. At times slight damage has resulted to other Umbelliferae including celeriac, fennel, coriander, caraway, and dill. Pettit (72, p.40) and Metcalf and Flint (63,p.514) record it also as infesting wild carrot, but Whitcomb (99, p.6) asserts that although this plant grows abundantly in eastern Massachusetts, the carrot rust fly has been neither found nor reported on it there. Chittenden (7, p.43) mentions a record from Scandinavia of finding Psila rosae on turnip and rape, and Pettit (72, p.40)

records it from turnip, rape, and potato. Whitcomb (99,p.7) states that as common and destructive as has been the rust fly in Massachusetts, it has been found attacking only members of the Umbelliferae, and concludes that these plants are at least preferred for food.

The only records found of relative susceptibility of different varieties of carrots come from Whitcomb (99,p.7) who sums up experiments conducted at Waltham from 1929 to 1933 thus:

> Of the garden varieties, it is apparent that the short, thicker varieties such as Chantenay and Scarlet Horn are less seriously damaged than the longer varieties such as Hutchinson and Intermediate, and yield records from Nova Scotia confirm these observations.
>
> At Waltham the stock carrots were generally more heavily infested than the garden carrots, as a group. Gorham (correspondence) states that in New Brunswick the white carrots suffer less injury than the red carrots, but at Waltham the White Mastodon and White Belgian varieties were very severely damaged in some cases and suffered more injury than the Long Orange Belgian.

Psila rosae is a small, delicate fly with a shiny dark green or black body. The head and legs are yellowish or pale yellowish brown. The eyes are generally described as black, but The Garden Encyclopedia (81, p.224) designates them as red. The proximal antennal segment is yellow, as is the head, but the distal segment or at least the tip of this segment is black. The body is scantily covered with a short yellowish pubescence. The thin wings are somewhat opaline and protrude beyond the abdomen by almost half their length.

The fly is from four to nearly five millimeters in length (less than a fifth of an inch long). Females are slightly larger than males and can be distinguished from them by the fact that their abdomens terminate in a sharp point, whereas the abdomen of the male is rounded posteriorly.

The greater number of flies emerge from the overwintering pupae between the twentieth of May and the thirteenth of June. Records of emergence as early as May sixteenth and as late as July tenth have been obtained. The time of emergence varies with the season, but usually coincides with the time at which early carrots are two to four inches long. Experiments by Whitcomb (99,p.12,13) show that the time of emergence is influenced both by temperature and soil moisture. In one experiment about two and one-half times as many flies emerged on days when the average temperature was 60 degrees F. or lower than when it was above 60 degrees F. His further experiments also indicated that comparatively low temperatures were more conducive to emergence, when twenty-five field-collected pupae were put in constant-temperature cabinets about six weeks before the usual emergence period. Over eighty percent of the pupae transformed in the cabinets kept at 55 degrees and 65 degrees F., only about one-half as many in the one kept at 75 degrees F., and none in the one kept at 85 degrees F.

A slightly or moderately moist soil was found most

advantageous to emergence. Whitcomb's experiments with this factor on four hundred pupae showed that the emergence from dry soil was thirty-three percent, from slightly moist soil eighty percent, and from wet soil fifty-four percent. In another experiment cages were used in which the soil saturation was kept at one hundred percent, seventy-five percent, fifty percent, and twenty-five percent, and the temperature was kept constant. The moisture of the soil was regulated by the addition of enough water to keep up a predetermined weight of soil in the cages. Using ten pupae to each cage, soil moistened to twenty-five percent saturation was most favorable.

Records show that female flies are slightly more abundant than males, although males are thought to predominate early in the season. The flies are short-lived, living on the average slightly over four days. The maximum record known is eleven days for one fly. Females lived a few hours longer than males on the average. It has been shown experimentally that lower temperatures increase the life span by two or three days or from fifty to seventy-five percent.

Soon after emergence the female lays her eggs singly in cracks in moist soil, on the soil near the bases of the plants, or on the crowns of the plants themselves. It is evident that the females distinguish between the qualities of carrots when they lay their eggs, preferring the more vigorous, normally-shaped ones.

Although the carrot rust fly lays its eggs singly, up to ten have been found together in a group. Freshly laid eggs have never been found further than two inches away from carrots. At first they are generally partly exposed among the little clumps of earth produced by cultivation, thinning, and weeding. The weather and artifical tending soon cover them slightly. Females laid an average number of eighteen eggs one year and six eggs the following year in experiments conducted by Whitcomb (99,p.14). Female flies have been known to lay as many as thirty-five eggs in their short existence. Temperatures of 55 degrees and 65 degrees F. were found to stimulate oviposition while temperatures of 75 degrees and 85 degrees F. were found to inhibit it. In experiments conducted during successive years the periods of greatest oviposition were June twenty-fifth to thirtieth, May twenty-seventh to June first, and June eleventh to fourteenth respectively. The earliest date recorded during this time was May eighteenth and the latest July ninth.

The white eggs are between six-tenths of a millimeter and one millimeter long, and only about one-fourth as wide. The egg is finely corrugated lengthwise and each depression has a series of hemispherical concavities along its length. These engravings are said to give it the appearance of the surface of a peanut shell. At one end of the egg is located a small protuberance about one-third as wide as the widest part of the egg.

In his incubation studies Whitcomb (99,p.15) placed the eggs on damp blotting paper in shallow covered glass dishes or on blocks of plaster of Paris set on moist sand. Under these conditions from fifty-five to ninety-five percent of the eggs hatched. The incubation period varied from three to seventeen days and averaged from about six to ten days. In constant-temperature studies, a temperature of fifty-five degrees Fahrenheit lengthened the incubation period to twenty days, temperatures of sixty-five and seventy-five degrees were found to be optimum, and a temperature of eighty-five degrees completely prevented hatching.

Though rather slender, the small legless larva is nevertheless a typical maggot. When it first leaves the egg it is colorless, with lusterless white spots. It begins to darken through shades of cream and yellow, and by the time it is ready to pupate has taken on a yellowish brown or straw color. Essig (24,p.607) and The Garden Encyclopedia (81,p.224) describe it as dark brown. The pointed head is equipped with two conspicuous black hooks for feeding. The posterior end, with its dark spiracles, terminates bluntly. The length of the carrot rust fly maggot varies between six and nine millimeters (between one-quarter inch and slightly over one-third inch). Its width is one or two millimeters.

The tiny larvae, upon hatching, work their way down into the soil, for on such crops as carrots and parsnips all

the damage is done below ground level. When carrots have grown to about one-quarter inch in diameter they are liable to attack by the maggots, which prefer the healthy, normal ones to the dwarfed or deformed ones. They feed for some time on the small roots, reaching the greater part of their growth before injuring the main root. Chupp and Leiby (10, p.99) consider this habit of great value to the grower, for they say it permits leaving late carrots in the ground for some time after the larvae of the second brood (to be mentioned below) have hatched, without danger of infestation.

First injury to the main root consists of narrow rusty-red furrows in the epidermis, about one-sixteenth of an inch deep. They may be sinuous tubular tunnels or larger irregular areasformed by the coalescence of individual trails. The channels may frequently break through to the outside, but more often such visible surface scars are entirely absent. It is common for the larvae to eat off the bottom of the tap-root in young carrots and parsnips, causing the plants to turn yellow and make a stunted growth. Although the burrows have some tendency to advance horizontally, soon they disperse in every direction, often riddling the whole root system in the month or so the larvae are active. The holes may extend right through from one side of the carrot to the other, although this is seldom the case in varieties that have a well-defined fibrous core. In experiments to determine the location of the

tunnels in carrots Whitcomb (99,p.9) concludes:

> In the larger carrots, which averaged eight inches in length, the maggots were quite evenly distributed from the second to the eighth inch with the greatest number being found in the fourth inch. In short carrots, which were 2 to 5 inches long, averaging 3.3 inches, and were also misshapen by earlier attacks of the rust fly, 70 percent of the maggots were found in the second and third inches.

The rusty color of the burrows in the flesh of carrots and parsnips has given the carrot rust fly its name. Unfortunately for diagnosis, such rusty scars are produced not by the rust fly alone, Any injury to the skin of carrots and parsnips causes a similar appearance. The foliage becomes sparse, especially when young plants are attacked, and as the leaves get older they take on a distinctly reddish or yellow hue.

Due to the work of _Psila rosae_ celery and parsley plants, after getting a good start, sometimes wither, and the outer leaves turn yellow. In these vegetables the small fibrous feeding roots are chewed off and when the attack is serious enough, maggots may also be found feeding in the fleshy stems above the ground. Celery may become infested in the seedbed as well as in the field if plants are present there at the time of oviposition.

The market value of even slightly infested carrots is diminished, badly damaged ones are valueless, and the

destruction of the carrot rust fly frequently renders a large percentage of the crop unsalable, It is especially common for the late carrot crop to be damaged to worthlessness. Unfortunately, injury may continue in stored carrots if the temperature is favorable. This fact, it would seem, may be in part responsible for the spread of the maggots to uninfested areas. Particularly injurious to stored carrots is an infestation where the maggots are still young at harvest and their presence is unnoticed.

The feeding period of the larva occupies about one month, records kept by Whitcomb (99, p.16) averaging about twenty-seven and one-half days in one year and about thirty days in another year. In Massachusetts, this feeding period of the first generation larvae usually occupies from the middle of June to the middle of July. Sometimes it may begin as early as the first of June; other times it may not end until the first of August. The pupal period is spent in the soil within one or two inches of the root in which the larvae were feeding and seldom more than six inches below the surface of the ground. The pupal period lasts approximately as long as the larval period. The first three days of the pupal period are spent in preparation for pupation, and during this time the insect is called a prepupa.

The lustrous amber brown puparia are usually from four and one-half to five millimeters long (about one-fifth of

an inch) and from one to one and one-quarter millimeters wide, but are rather variable in regard to size. Posteriorly they are cut off at a slanting angle and it is this part that is forced open like a hinged lid when the adults emerge.

The entire life cycle of the members of the first generation consumes from nine to eleven weeks. The second generation takes about the same length of time to develop. Eggs of this second generation are laid in August. The abundance of this generation is reduced, probably by one-half of that of the first generation, due to the hot, dry weather usually prevalent at that season. Pupation takes place within four or five days of the maturation of the larvae, which is usually between the first of September and the time when the soil freezes. In many localities there is often a partial or a whole third generation.

Certain writers speak of the carrot rust fly's passing the winter as larvae, rather than or as well as pupae. The larvae thus referred to are probably of the third, or possibly in some localities, of the second generation. Matheson (61, p.422) asserts that the larvae of the second generation hibernate. Metcalf and Flint (63, p.514) contend that the winter may be passed either as larvae in the roots or as pupae in the soil. Other sources consulted refer only to pupal hibernation.

Control. As late as 1928 Metcalf and Flint (63,p.514) stated that no practical control for Psila rosae had been worked out. The control methods suggested by various authors both before and after this date are numerous, and the diverse cultural practices advocated will be treated first. Such practices, if handled properly by man, can at least reduce the amount of injury caused by the pest.

The destruction of weedy hosts in uncultivated neighboring fields and along roadsides is an essential step. Also, rotation of crops serves to eradicate the rust fly from an area. To many growers it would be impractical to run their farms without growing any of the economically important Umbelliferae. Such extreme measures should be resorted to only in an emergency, such as in a year following unusually severe damage by the rust fly. In any case, the growing of host plants on the same land year after year should be discouraged.

Likewise to be avoided is the growing of both early and late crops of celery or carrots in the same year. This habit encourages the firm establishment of the first brood of the rust fly on the early crop, and the numerous progeny of this generation causes maximum injury to the late crop. Elimination of the early crop is the only suitable procedure, and Whitcomb (99, p.2,23) reports that in Massachusetts at least, the first generation can be completely avoided by planting

late crops June tenth to fifteenth.

The planting date is an important factor in itself. Where it is not practicable to discontinue the early crop, planting after June the first and making a slightly premature harvest in early September sandwiches the crop in between the first and second broods of the rust fly. By thus shortening the season, the crop yield will probably be somewhat diminished, but the fact that the harvest produced is free from injury and all marketable more than balances any decrease in quantity. If this procedure is followed with carrots, it is best to plant a variety that matures in sixty-five to seventy days. The date June the first, before which the main crop should not be planted, is given both by Whitcomb (99, p.23) for Massachusetts and by Chupp and Leiby (10, p.91).for New York.Therefore in these areas early crops should be planted on or just after June first and late crops should be planted just before or on June fifteenth.

Another cultural practice is to grow carrots interplanted with rows of onions, which have a repellent effect on the rust fly. Such a measure should be employed only where the grower can profitably produce and market both crops, for tests show that rust fly infestation is only slightly reduced thus.

If irrigation is being employed, it is wise to suspend it during the fly's egg-laying period, for a dry soil discourages oviposition. This factor should be considered

when choosing a site for carrot raising, for their growth should not be attempted in cool, moist fields.

In the home garden carrots may be grown under a tightly-constructed cheesecloth screen during the egg-laying period. Chupp and Leiby (10, p.92) recommend cloth with from twenty-four to thirty threads an inch and advise its use over celery seedbeds. They caution that soil chosen for a seedbed must be carefully examined against the possibility of its containing wintering-over pupae. Such infested soil would be particularly undesirable in a bed covered with cheesecloth, for the damage of the trapped emerging flies would then be concentrated directly on the crop.

The use of mulch paper is another cultural measure satisfactory for the home garden, but too laborious and costly for use on commercial plantings. Mulch paper is valuable because it is impermeable and covered with a layer of asphalt which gives off a repellent odor. Mulch paper should be applied as soon as the tiny plants are high enough to indicate the rows clearly, and may be used on early crops only. The use of mulch paper is to be strictly avoided on late crops, forthere it provides an ideal moist, sheltered place for oviposition. Neither should carrots be thinned at the height of oviposition,for the loosened soil would provide attractive lodging places for the eggs.

The only source found to advise against the use of

fresh manure is O'Kane (66, p.123), but such a practice is generally inadvisable anyway.

Cultivation is decidedly worthwhile, although the larvae and pupae of Psila rosae are less harmed by it than are those of many species. While Peairs (70, p.264) prescribes deep plowing in either late fall or early spring, Whitcomb (99, p.2) recommends, for the late autumn only, a light harrowing to turn up the maggots and pupae to the alternate freezing and thawing of winter. He approves of deep plowing in the spring, with its object being to turn the hibernating pupae under the soil.

We have previously seen that it is advisable to harvest the crop in early September to prevent attack by second brood maggots. Pettit (72, p.41) suggests that a slightly premature harvest may not be necessary:

> It has been stated that the maggots work at first on the small roots before attacking the main roots. This makes it possible to leave the carrots in somewhat longer than if the attack were made immediately on the tap root.

Chupp and Leiby (10, p.91) give directions for growers desiring to defer the harvest as long as possible. They warn that the field should be carefully examined at least twice a week starting about the first of September. They claim that even a light infestation can be made known by scraping with a knife blade carrots pulled from various parts of the field. They admonish that harvest must begin immediately upon finding

any larvae in the carrots. It seems that such a practice would necessitate planting the field to some non-umbelliferous plant the succeeding year.

Infested carrots or parsnips must never be left in the ground at harvest, particularly those so damaged as to be unmarketable. Neither may they be left lying in the field, but should be disposed of at once in one of the ways mentioned by Whitcomb (99, p. 2). They may be burned with oil, buried with quicklime under a foot of firmly packed soil, or fed to farm animals in the barn (never in the fields, of course). Statistics compiled by the same investigator (99, p. 11) over a period of four years revealed that where carrots were left in the ground twenty-five to eighty times more pupae were found than where the carrots were pulled and taken from the field.

To be destroyed in the same way are all roots in storage found to be infested. It is generally not considered practical to fumigate infested carrots in storage, but if such fumigation is undertaken, carbon disulfide should be used for eighteen hours at the rate of four ounces for each one hundred cubic feet. Receptacles which have contained infested carrots should be fumigated thus or otherwise cleaned.

These various cultural practices are so stressed because the treatment of carrots with dusts or sprays for insect pests is in most areas, including Massachusetts, considered uneconomical. Nevertheless, insecticides may be used

profitably under certain circumstances, the chief one being in an area where a yield of five hundred or more bushels an acre can be obtained. They are also advised for use in seasons when severe injury by the rust fly places a premium on undamaged carrots. In any case, if early carrots are planted before the first of June the use of insecticides will quite surely be found necessary. Treatments should begin about the first of June on these early crops, and about the first of August on late carrots. Three or four applications about one week apart are essential to good control,and of course heavy rains necessitate more frequent applications.

A method of seed treatment has been devised, similar to that used for the control of root maggots in cabbage, onion, and cauliflower. The carrot seed is placed with one-half its weight of powdered calomel (mercurous chloride) in a closed container. The mixture is shaken until all of the seed has become coated with calomel. This treatment is given just before the seed is planted. Pure calomel is recommended, as gradually increasing dilutions of the calomel with clay have proved less and less satisfactory. While this treatment provides good protection for the early carrot crop against the first brood, it has proved not so effective in protecting late carrots against the second brood.

A further reduction of infestation may be gained by sprinkling calomel in the seed drill as well as on the seed,

but the gain is not sufficient to warrant the additional expense entailed. Seed treatment tests have been made using corrosive sublimate (mercuric chloride) instead of calomel. Even when the corrosive sublimate was diluted with clay to only fifteen percent, the seed was so injured that very poor germination ensued.

Whitcomb (99,p.24-33) has made extensive tests, both in the laboratory and in the field, on several dusts and sprays. Since in the following discussion references will be made to the results of these tests, it will be well to outline briefly here the conditions of his experiments.

In the laboratory, eggs were placed on moist blotting paper in Petri dishes and thoroughly sprayed or dusted. Newly emerged adult flies were confined in groups of ten in lantern globe cages over potted carrots which had been sprayed or dusted with various insecticides. When dusts were employed, the flies were enclosed with the plants right after the dust had been applied. When liquids were employed, the flies were not confined with the sprayed plants until the spray had dried.

In the field experiments a plunger type duster was used. Although the dusts were directed onto the plants from only one side, care was taken to reach the crown of the carrot and the soil adjoining it. The foliage of seedlings under two inches high was covered with dust applied from above. The tops of the larger carrots could not be so completely covered. The

dusts were used at about one-quarter of a pound per one hundred feet of row, which is about seventy-five pounds an acre.

Liquids were dispersed from compressed-air knapsack sprayers, with the nozzle held close enough to the ground to insure coverage of crown and adjacent soil.

In the laboratory experiments the eggs and adults were destroyed more quickly and consistently by derris (containing six-tenths percent rotenone) than by other insecticides. When flies were confined with plants dusted with undiluted ground derris root as long as four days after the dust was applied, all of the flies were dead in twenty-four hours. Unfortunately, undiluted ground derris root is too expensive for use on carrots. Later a cubé-clay dust (containing six-tenths percent rotenone) effectively combated a light attack. This mixture is recommended by Whitcomb (99, p.35).

If a cost of five or ten cents per bushel is possible the derris or cubé should be applied to early carrots in three treatments, a week apart, beginning May twenty-fifth in early seasons and June the first in late seasons. The mixture is used at the rate of one-quarter to one-half pound to each one hundred feet of row.

Sprays containing rotenone have also proved quite effectual, though they are usually more laborious to apply. Pyrethrum is not as effective as derris or cubé, either as a spray or as a dust.

A Bordeaux-oil emulsion almost identical with that used to control the onion maggot, is said by some to provide at least a certain amount of control for the carrot rust fly. Metcalf and Flint (63, p.492) recommend combining forty-eight and one-half gallons of a four-six-fifty Bordeaux mixture with one and one-half gallons of lubricating-oil stock emulsion. They give detailed directions for the preparation of the Bordeaux mixture on pages 260 to 262 inclusive and for the preparation of the lubricating-oil stock emulsion on pages 250 and 251. These writers even go so far as to say that this preparation will give practically one hundred percent control when applied in five applications at weekly intervals, the first when the plants are an inch high. The soil about the roots of the plants is thoroughly soaked with the mixture.

Pettit (72, p.41-42) writes that a two percent Bordeaux-oil emulsion is said to give some measure of protection Whitcomb (99, p.33) found spraying with a one percent lubricating-oil emulsion and a one percent oil emulsion in a four-four-fifty Bordeaux mixture so unsatisfactory as to call for no further experimentation. He found that it gave fairly good protection to the carrot but did not kill the flies rapidly or reliably.

Similar results were obtained by Whitcomb in tests with corrosive sublimate, sulphur, sodium and calcium fluosilicates, and nicotine. In fact, in an experiment with a solution of nicotine sulfate containing fifty percent nicotine

diluted one to five hundred, the sprayed plants were so much more damaged than the controls that it was suspected that nicotine may act as an attrahent to the flies. (Nevertheless, the same authority has found ground tobacco, containing nicotine, to be a valuable repellent. See p.168). Although the corrosive sublimate gave some control when used at the rate of one ounce in seven and one-half gallons of water, it not only stunted the growth of carrots, but also caused rough blotchy areas on the surface of the carrot, called mercury russet.

The Garden Encyclopedia (81,p.224) advises the use of a spray composed of three or four ounces of calomel to ten gallons of water. Chupp and Leiby (10, p.92) direct that this suspension of calomel must be constantly agitated during application to prevent settling. They recommend its use at the rate of one gallon to from thirty to forty feet of row. They state that satisfactory control should be obtained from two or three successive applications for each brood a week or ten days apart, the first one being applied at the earliest sign of the flies. Whitcomb (99,p.29) used calomel at the lower rate of one ounce in five gallons of water. This mixture did not stunt the carrots as did the corrosive sublimate used by him, but three applications of it failed to control the rust fly. He reports concerning experiments with dusts containing two and four percent calomel in lime or gypsum fair control during two light infestations but failure during a heavier infestation.

Of the repellents employed for the control of Psila rosae the most outstanding one is naphthalene. While primarily a repellent, naphthalene also kills the eggs and the newly hatched larvae by contact and fumes. Crude naphthalene or naphthalene flakes are broadcast by hand between the rows in among the crowns of the plants. Peairs (70, p.264) states that it should be used in six treatments at the rate of four hundred pounds an acre for each application. He proposes that the first application be made late in July at the first signs of the appearance of the second brood. The other applications should follow at weekly intervals until the peak of emergence has well passed. Whitcomb (99,p.3) advances a slightly lower concentration for use on late carrots if it is practicable to incur an expense of ten cents a bushel. He uses the naphthalene in four treatments at intervals of a week, beginning about the first of August. He has found satisfactory the rate of one pound naphthalene to each one hundred feet of row. This rate amounts to about three hundred and fifty pounds an acre and entails a cost of approximately fourteen dollars an acre.

Whitcomb also advises the use of naphthalene on early carrots at the same rate, in three applications at weekly intervals, commencing the twenty-fifth of May in early seasons and the first of June in late seasons. If the flakes are in lumps they should be crumbled by hand before being

scattered, to prevent uneven distribution and waste. Fortunately there results from naphthalene no injury to the leaves or roots of carrots. A slight though noticeable stimulation to the plants has resulted from its use. The reason for this stimulation is not known.

Chupp and Leiby (10, p.99) recommend naphthalene also for use on celery seedbeds where an infestation has been predicted and the use of cheesecloth screens is impracticable. They claim complete protection when one pound of pure naphthalene is broadcast over each one hundred square feet of seedbed in two or three treatments about a week apart, beginning from May twentieth to twenty-fifth.

Two cautions must be kept in mind when employing a repellent such as naphthalene. First, such volatile crystals may evaporate in less than a week in very warm weather, necessitating a shortening of the periods between applications. In the second place, the repellency of these materials is greatly impaired when they are wet.

A mixture of equal parts of sulfur and naphthalene does not give as good protection as does pure paphthalene. Two other repellents which give good control in the same number of applications as naphthalene are available at slightly greater cost. One, ground tobacco containing from one to one and one-quarter percent nicotine, should be used at the rate of two pounds to each one hundred feet of row. The other,

Scotch soot, is a popular plant stimulant among the British and has to be imported. Scotch soot is a fine black powder composed chiefly of carbon and deposited in the chimneys and flues in Scotland. There is no reason why French, German, or Boston soot would not be just as effective if it were available, that is, gathered and put on the market, as is that deposited in Scotland. It should be applied at the rate of three or four pounds to each one hundred feet of row.

Talc, limestone, and wood ashes also form a powdery coating distasteful to the flies, but their action is merely mechanical and is not capable against heavy infestations on commercial plantings. Their cheapness makes them desirable for use against light outbreaks in home gardens.

PART III. -- SUMMARY.

CHAPTER V. -- SUMMARY.

The insects within the scope of this paper are studied in regard to structure, habits, and life history. In each case the methods of control are discussed. The methods are always planned in accordance with the preceding factors. Only insects with complete metamorphosis are considered. The lives of these insects may be divided into four stages -- egg, larva, pupa, and adult.

The Umbelliferae are widespread herbaceous plants characterized by the flattened clusters, or umbels, in which their flowers are borne. The Umbelliferae of greatest economic importance in the United States are parsley, celery, carrot, and parsnip. Parsley and celery are usually grown for the parts of the plant borne above ground. Parsley is used chiefly for garnishing meat dishes and flavoring soups and salads. Celery is one of our most commonly used raw vegetables in the winter season. Carrot and parsnip are grown for their large sweet tap-roots, which are used as food both for human beings and domestic animals.

During the past few decades the problem of insect control on umbelliferous crops has assumed increasing importance. The large commercial plantings of these crops to supply the demands of the canning industry have greatly favored the multiplication of some insects by concentrating their food supply.

Three of the orders of holometabolous insects, the *Coleoptera*, *Lepidoptera*, and *Diptera* , contain members which attack the economically important *Umbelliferae*. The injurious species are arranged under these orders by families. The general feeders, whose attacks on the *Umbelliferae* are merely incidental, are mentioned briefly. The species which manifest a preference for the *Umbelliferae* are treated in detail. The accounts of these insects include the following information:

1. distribution
2. host plants
3. description of each stage of the life cycle
4. nature and extent of the injury caused
5. control measures

The *Coleoptera*, or beetles, is the largest order of insects. They have stout bodies, tough exoskeletons, and chewing mouthparts. Their horny or leathery forewings, called elytra, form a protective covering for their delicate membranous hindwings. These lie folded beneath the elytra when not being used for flying. The larvae, often known as grubs, form exarate pupae.

Four families of beetles contain general feeders which have been known to injure one or more members of the Carrot Family. The *Elateridae* are called click beetles as adults and wireworms as larvae. A number of species of wireworms are economically important because of the damage they do to the roots of plants. The injuries suffered by carrots from wireworms have not been

assigned to any particular species.

The Meloidae, or blister beetles, also contains a variety of general feeders which as a group attack numerous crops including carrots. In the Chrysomelidae there are two species of flea beetles[1] which occasionally damage umbelliferous crops. The Scarabaeidae include a group of species[2] known in the adult stage as May beetles or June bugs and in the larval stage as white grubs. They, as well as the Asiatic garden beetle,[3] are general feeders that sometimes damage carrots.

Another scarabaeid, the carrot beetle,[4] is a widely distributed species which shows a marked preference for the Umbelliferae. The adults are heavily built, shining reddish brown beetles which hibernate in the soil. During the spring and summer they excavate in the bases of celery stalks and in the roots of carrots and parsnips. The larvae feed upon decaying vegetation in the soil and upon the roots of grasses, grains, and weeds. Only cultural practices are recommended for controlling the carrot beetle. Probably the most important cultural practice is deep plowing in the late summer or fall.

Two weevils which belong to the Curculionidae are of particular importance to the growers of umbelliferous crops. One is the vegetable weevil,[5] a pest now present in the Gulf States and in the San Francisco Bay region. The larvae of this

---

[1] Epitrix cucumeris Harris and Systena taeniata (Say)
[2] Genus Phyllophaga
[3] Auto-serica castanea (Arrow)
[4] Ligyrus gibbosus (DeGeer)
[5] Listroderes obliquus Gyllenhal

species feed by preference upon the foliage of carrots and turnips.

Field sanitation and planned crop rotation soon starve out the vegetable weevil. During the winter months the use of a disk harrow followed by a clod breaker destroys large numbers of the very delicate pupae which are found just below the surface of the soil. In the spring, poisoned bran baits containing fruits or fruit juices are effective against the gregarious adults.

The quickest and surest control of the vegetable weevil is obtained by employing insecticides. A calcium arsenate dust or spray may be used on foliage that is not to be eaten by human beings or animals. Various fluorine compounds may be used safely if the precautions which we describe are observed. The poisons should be applied as soon as the first larval injury to carrots or turnips is noticed.

The other curculionid is the carrot weevil,[6] most abundant in the state of New York. The adults are dark brown beetles covered with golden or copper-colored scales. They have well-developed wings, but fly little and therefore spread slowly. The rather active, flattened, relatively slightly curved grubs injure the stems and roots of plants.

The carrot weevil is decidedly specific for the Umbelliferae. Fortunately, the numbers of the pest have never

---

[6] Listronotus latiusculus (Boheman)

increased enough to attract much attention. Crop rotation alone serves to banish it from an area. Arsenical baits and sprays have proved effective when used experimentally against the carrot weevil.

The Lepidoptera are called moths or butterflies as adults. They usually have two large pairs of membranous, scale-covered wings which in flight function as one pair. The larvae are called caterpillars. They are worm-like and may or may not be covered with hairs. Moths pupate within silken cocoons which the larvae spin about themselves. Butterflies pass the pupal stage in a specialized pupal case known as a chrysalis.

Two families of Lepidoptera include one general feeder each which sometimes damages Umbelliferae. The oblique-banded leaf roller,[7] which belongs to the Tortricidae, has been said to damage celery. The species is most important as a pest of trees and shrubs. The caterpillars are light yellowish green or reddish and only slightly hairy. They feed at first upon young leaves and later upon developing flower buds around which they have rolled and tied with silk one or several leaves. Infested buds should be cut off and burned. During the winter oil-emulsion sprays will kill the eggs. In the spring applications of arsenicals are effective against the young larvae.

---

[7] Archips rosaceana (Harris)

The yellow woolly-bear[8] belongs to the Arctiidae and is a general feeder on flowers and vegetables including carrot, celery, and parsnip. The adult is a snow-white moth dotted with black or brown. The larvae are covered with numerous, long, light or dark-colored hairs which are liberally used in the construction of the cocoon. Although the larvae are such general feeders they rarely become numerous enough to cause much damage. Handpicking is normally all that is necessary to control them.

Nine species of Noctuidae have been found feeding on various members of the Carrot Family. None of these species is of serious concern to growers of umbelliferous crops. Three species of cutworms are involved. Two of them, the spotted cutworm[9] and the well-marked cutworm,[10] exhibit climbing tendencies. They may be controlled by the use of poisoned baits. The third species, the pale western cutworm,[11] cannot be controlled by the use of poisoned baits for it is chiefly an underground worker. Cultural practices, especially soil cultivation, are beneficial in reducing the numbers of this cutworm. Crop rotation and the introduction of irrigation are advised by reliable sources.

Cultural practices must be relied upon also for the control of the common stalk borer.[12] Infested stalks should be removed or the borers cut out of them with a knife. The cabbage

---

[8] Diacrisia virginica (Fabricius)
[9] Agrotis c-nigrum Linnaeus
[11] Porosagrotis orthogonia Morrison
[10] Agrotis unicolor Wlk.
[12] Papaipema nebris (Guenée)

looper[13] and the celery looper[14] are distinctive noctuids. The middle portion of the body of these caterpillars lacks legs and is humped up when the insect is moving or at rest. The cabbage looper is a very serious pest of crucifers. The celery looper shows some preference for the Umbelliferae. Both species feed upon the foliage and can be controlled by spraying the plants with stomach poisons.

The same poisons that destroy these loopers are effective against the semi-tropical armyworm[15] and against two bright black and yellow-striped caterpillars of the genus Mamestra.[16]

The Pyralididae contains one of the most important umbelliferous pests, the celery leaf-tier.[17] In addition to being found almost everywhere that celery is grown, this species is also a serious pest in greenhouses. The adult is a dull gray or brown moth with irregular lines marking its wings. The slender larvae bear green and white longitudinal stripes. The larvae tie leaves together and feed upon them as well as upon the flowers and stems of plants. Pyrethrum has been found to be the most valuable insecticide for preventing the leaf-tier from damaging celery.

---

[13] Autographa brassicae (Riley)
[14] Autographa falcifera (Kirby)
[15] Xylomyges eridania Cramer
[16] Mamestra legitima Grote(the striped garden caterpillar) and and M. picta Harris (the zebra caterpillar.)
[17] Phlyctoenia ferrugalis Hübner

A markedly specific pest of the Carrot Family, the parsnip webworm,[18] belongs to the Oecophoridae. The species occurs in northeastern United States and southern Canada. The adult is a small dark gray moth. The yellowish-green or grayish-green larvae are covered with small black spots and short hairs. They web together and feed upon the leaves and developing flower heads of their hosts.

The eradication of umbelliferous weeds from an area and the destruction of infested flower heads are the best means of controlling the parsnip webworm. Arsenical sprays are sometimes used, but it is difficult for them to reach the concealed worms.

The celery worm,[19] another very specific pest of the Carrot Family, belongs to the Papilionidae. Although it is commoner than the parsnip webworm it is less troublesome. The beautiful adult swallowtails are large black butterflies with yellow-spotted wings. The smooth, naked caterpillars are strikingly striped and spotted with black, green, and bright yellow. They feed upon the foliage but seldom cause enough damage to warrant any control other than handpicking.

The Diptera under consideration are called flies in the adult stage. They are small insects with only one pair of wings -- the forewings. The hindwings are represented only

---

[18] Depressaria heracliana (DeGeer)

[19] Papilio polyxenes Fabricius

by short, knobbed stalks, which may be associated with the sense of balance. The larvae of flies are called maggots. They lack true legs, and a number of them possess no distinct head. Many pupate within the last larval skin, which is known as a puparium.

The cabbage maggot[20] belongs to the Anthomyiidae. It sometimes infests celery slightly, but is known primarily for the great amount of damage it causes the cruciferous plants.

The Trypetidae are the fruit flies. One of them, the parsnip leaf-miner,[21] is a specific though rather uncommon pest of the Carrot Family in the United States. The adults are yellow and measure only three-sixteenths of an inch long.

The maggots mine in the leaves of plants causing them to wither and die. The use of repellent dusts or sprays on the foliage keeps the females from laying eggs there.

The Psilidae is a small family. One member, the carrot rust fly,[22] is a dangerous enemy of carrots and celery. This shiny dark green or black fly is now prevalent in northeastern United States. The typical maggots darken in color from dull white to straw-color during their development. They produce numerous irregular rust-red burrows in the roots of carrots and parsnips. They attack the small fibrous feeding roots and sometimes even the stalks of celery and parsley.

---

[20] Hylemyia brassicae (Bouché)
[21] Acidia fratria (Loew)
[22] Psila rosae (Fabricius)

Correct timing of planting and harvesting makes it possible for carrot crops to avoid both broods of the rust fly. Crop rotation and destruction of umbelliferous weeds are cultural practices that must be observed in rust fly infested districts.

It is profitable to use insecticides on carrot crops only when high yields are expected or when widespread and severe damage by the rust fly places a premium on carrots. The treatment of carrot seed with a calomel mixture has been found advantageous. Sprays or dusts containing nicotine have proved most effective in destroying the eggs and adults. Naphthalene has been found to be the most valuable repellent.

BIBLIOGRAPHY.

1. Brittain, W. H., "Experiments in the Control of the Cabbage Maggot (Chortophila brassicae Bouché)", Proceedings of the Entomological Society of Nova Scotia for 1919. No.5, 41-66. Truro, Nova Scotia: Feb. 1920.

2. Brittain, W. H., and A. D. Pickett, Injurious Insects of Nova Scotia, Part II. Halifax, Nova Scotia: Nova Scotia Dept. Agr. (Entomological Division) Bul. 12 (revised) 1938. 159 pp.

3. Brues, Charles Thomas, Insects and Human Welfare. Cambridge, Mass.: Harvard University Press, 1920.

4. Burgess, A. F., and C. W. Collins, "The Value of Predacious Beetles in Destroying Insect Pests." U. S. Dept. Agr. Yearbook, 453-466. Washington, D. C.: 1911.

5. Carpenter, George Herbert, Insect Transformation. New York: Dodd, Mead and Company, 1923.

6. Chittenden, F. H., Some Insects Injurious to the Violet, Rose, and Other Ornamental Plants. Washington, D. C. : U. S. Dept. Agr. Ent. Bul. 27, 1901. 114 pp.

7. Chittenden, F. H., A Brief Account of the Principal Insect Enemies of the Sugar Beet. Washington, D. C.: U. S. Dept. Agr. Ent. Bul. 43,1903. 71 pp.

8. Chittenden, F. H., Some Insects Injurious to Truck Crops. Washington, D. C.: U. S. Dept. Agr. Ent. Bul. 66, Part III, 1907. 32 pp.

9. Chittenden, F. H., Some Insects Injurious to Truck Crops. Washington, D. C.: U. S. Dept. Agr. Ent. Bul. 82, Part II, 1909. 24 pp.

10. Chupp, Charles, and R. W. Leiby, The Control of Diseases and Insects Affecting Vegetable Crops. Ithaca, New York: N.Y. State Col. of Agr., Cornell Univ. Extension Bul.206, Feb.1931, revised Feb. 1944. 124 pp.

BIBLIOGRAPHY -- CONT'D.

11. Cocks, T. W., Insect Control in the Home Garden. Storrs, Conn.: Conn. State Col. Extension Service Bul. 185, May 1933. 8 pp.

12. Comstock, John Henry, An Introduction to Entomology. Ithaca, New York: Comstock Publishing Co., 1920. First Complete Edition, Third Edition of Part I.

13. Comstock, John Henry, and Anna Botsford Comstock, A Manual for the Study of Insects. New York: Comstock Publishing Co., 1904.

14. Conradi, A. F., and H. C. Eagerton, Corn and Cotton Wireworm, (Horistonotus uhlerii, Horn). Clemson College, South Carolina: So. Carolina Agr. Exp. Sta. Bul. 180, December 1914. 15 pp.

15. Cook, W. C., Field Studies of the Pale Western Cutworm. Bozeman, Montana: Univ. of Montana, Agr. Exp. Bul.225, February 1930. 79 pp.

16. Cowan, Frank, History of Insects. Philadelphia: J. B. Lippincott and Co., 1865. 396 pp.

17. Crosby, C. R., Charles Chupp, and R. W. Leiby, The Control of Diseases and Insects Affecting Vegetable Crops on Long Island. Ithaca, N. Y.: N. Y. State Col. of Agriculture, Cornell Univ. Ext. Bul. 278, Jan. 1934, revised Feb. 1933.

18. Dawson, R. W, "A Synopsis of the Scarabaeidae of Nebraska (Coleoptera)", The University Studies of the University of Nebraska, 22: 163-244. Lincoln, Neb.: Published by the University, 1922.

19. Dempsey, Paul W., White Grubs. Article in Boston Sunday Globe, May 20, 1945.

20. Dirks, Charles O., Biological Studies of Maine Moths by Light Trap Methods. Orono, Maine, Univ.of Maine, Agr. Exp. Sta. Bul. 389,Nov.1937.162 pp.

21. Doane, Rennie W., Common Pests. Springfield, Illinois: Charles C. Thomas, Publisher, 1931.

22. Duncan, Carl Dudley, and Gayle Pickwell, The World of Insects. New York and London:McGraw-Hill Book Co., 1939.

BIBLIOGRAPHY, -- CONT'D.

23. Ealand, C. A., Insects and Man. New York: The Century Co., 1915.

24. Essig, Edward Oliver, Insects of Western North America. New York: The MacMillan Co., 1926.

25. Essig, Edward Oliver, and W. M. Hoskins, Insects and Other Pests Attacking Agricultural Crops. Berkeley, Calif: Univ. of Calif., Col. of Agr. Extension Service 87, Sept. 1934, 155 pp.

26. Fabre, Jean Henri, The Wonders of Instinct. Translated by Alexander Teixeira de Mattos and Bernard Miall. New York: The Century Co., 1918.

27. Fernald, H. T., and Harold H. Shepard, Applied Entomology. New York and London: McGraw-Hill Book Co., Inc., 1942.

28. Folsom, Justus Watson, Entomology with Special Reference to its Biological and Economic Aspects. Philadelphia: P. Blakiston's Son and Co., 1906.

29. Folsom, Justus Watson, Entomology with Special Reference to its Ecological Aspects. Philadelphia: P. Blakiston's Son and Co., n.d. (Copyright 1922).

30. Forbes, Stephen A., Insect Injuries to the Seed and Root of Indian Corn. Urbana, Ill.: Univ. of Illinois, Agr. Exp. Sta. Bul. 44, May, 1896, 87 pp. (pp. 209-296 inc.)

31. Forbes, Stephen A., The More Important Insect Injuries to Indian Corn. Urbana, Ill.: Univ. of Illinois, Agr. Exp. Sta. Bul. 95, Nov. 1904. 69 pp. (pp. 331-399 inc.)

32. Forbes, Stephen A., On the Life History, Habits, and Economic Relations of the White Grubs and May-Beetles. Urbana, Ill.: Univ. of Illinois, Agr. Exp. Sta. Bul. 116, August, 1907. pp. 447-480 inc.

33. Forbes, Stephen A., A General Survey of the May-Beetles (Phyllophaga) of Illinois. Urbana, Ill.: Univ. of Illinois, Agr. Exp. Sta. Bul. 186, Feb. 1916. pp. 215-257 inc.

34. Forbes, Stephen A., The Influence of Trees and Crops on Injury by White-Grubs. Urbana, Ill.: Univ. of Illinois, Agr. Exp. Sta. Bul. 187, Feb. 1916. pp. 261-265 inc.

BIBLIOGRAPHY, CONT'D.

35. Friend, Roger B., The Asiatic Beetle in Connecticut. New Haven, Conn.: Conn. Agr. Exp.Sta. Bul. 304, March 1929. pp.585-668 inc.

36. Frost, S. W., General Entomology. New York and London: McGraw-Hill Book Co., Inc.,1942.

37. Gibson, Arthur, and W. A. Ross, Insects Affecting Greenhouse Plants. Ottawa, Canada: Dominion of Canada Dept. Agr. Bul.7 n.s., June 1922. 63 pp.

38. Gibson, Arthur, and R. C. Treherne, The Cabbage Root Maggot and its Control in Canada. Ottawa, Canada; Dept. Agr. Bul.12, 1916. 58 pp.

39. Gilbert, W. W., and C.H.Popenoe, Diseases and Insects of Garden Vegetables. Washington, D. C.: U.S. Dept. Agr. Farmers' Bul.1371, Issued Jan.1924, revised May 1924. 46 pp.

40. Glasgow, Hugh, "The Cabbage Root Maggot", in P. J. Parrott, Common Insect Pests of New York. Geneva, N.Y.:New York State Agr. Exp. Sta. Circular 164, July 1, 1937, revised March 1,1941.4 pp.

41. Gould, George E., Insect Pests of Muck Crops. Lafayette, Ind.: Purdue Univ. Agr. Exp. Sta. Circular 223, Sept. 1936. 20 pp.

42. Graham, Samuel Alexander, Principles of Forest Entomology. New York: McGraw-Hill Book Co., Inc, 1929.

43. Griswold, Grace H., Common Insects of the Flower Garden. Ithaca, N.Y.: New York State Col. of Agr., Cornell Univ. Extension Bul.371, March 1937, revised Feb. 1938. 59 pp.

44. Hallock, H.C., and I.M. Hawley, Life History and Control of the Asiatic Garden Beetle. Washington,D.C.: U.S. Dept. Agr. Circular 246, issued Dec. 1932, revised Oct. 1936. 20 pp.

45. Hammond, G.H., Control of White Grubs. Ottawa, Canada: Dom. of Can. Dept. of Agr.Wartime Production Series Special Pamphlet 39, 1940. 4 pp.

BIBLIOGRAPHY, CONT'D.

46. Hammond, G. H., White Grubs and Their Control in Eastern Canada. Ottawa, Canada: Com. of Canada, Dept. Agr. Publication 668, Farmers' Bul. 86, Apr. 1940. 18 pp.

47. Hawkins, John H., The Bionomics and Control of Wireworms in Maine. Orono, Maine: Univ. of Maine, Agr. Exp. Sta. Bul. 381, April 1936. 162 pp.

48. Herms, Wm. B., Medical and Veterinary Entomology. New York: The MacMillan Company, 1923.

49. Herrick, Glen W., Insect Enemies of Shade-Trees. Ithaca, N. Y.: Comstock Publishing Co. Inc., 1935.

50. Howard, L. O., The Insect Menace. New York: The Century Company, n.d. (copyright 1931).

51. Howard, L. O., Fighting the Insects. New York: The Macmillan Co., 1933.

52. Hutson, Ray, Chewing Insects Affecting Garden Crops. E. Lansing, Mich.: Michigan State Col. Ext. Div. Bul. 180, June 1937. 44 pp.

53. Hyslop, James A., Papers on Cereal and Forage Insects. Washington, D. C.: U. S. Dept. Agr. Ent. Bul. 95, Part VI, May 31, 1912. pp.89-108 inc.

54. Imms, A. D., A General Textbook of Entomology. New York: E. P. Dutton and Company,n.d.

55. Kellogg, Vernon L., American Insects. New York: Henry Holt and Company, n. d. Third edition, revised, copyright 1904, 1908.

56. King, Kenneth M., et al., Wireworm Control in Western Grain Fields. Ottawa, Canada: Dom. of Canada Dept. Agr. Wartime Production Series Special Pamphlet 37, 1940. 4 pp.

57. Lacroix, Donald S., Insect Pests of Growing Tobacco in Connecticut. New Haven, Conn.: Conn. Agr. Exp. Sta. Bul. 379, Dec. 1935. 130 pp.

58. Lovell, Oliver H., The Vegetable Weevil, Listroderes Obliquus. Berkeley, Calif.: Univ. of Calif., Dec. 1932.

BIBLIOGRAPHY, CONT'D.

59. Luginbill, Philip, Control of Common White Grubs in Cereal and Forage Crops. Washington, D. C.: U. S. Dept. Agr. Farmers' Bul, 1798, April 1938. 20 pp.

60. Lutz, Frank Eugene, Field Book of Insects. New York and London: G. P. Putnam's Sons, n. d. (copyright 1921).

61. Matheson, Robert, Entomology for Introductory Courses. Ithaca, N. Y.: Comstock Publishing Co., Inc., 1944.

62. McDaniel, E. I., Insect and Allied Pests of Plants Grown Under Glass. E. Lansing, Mich.: Mich. State Col. of Agr. and Applied Science, Agr. Exp. Sta. Special Bul.24, June 1931, 117 pp.

63. Metcalf, C. L., and W. P. Flint, Destructive and Useful Insects. New York: McGraw-Hill Book Co., Inc., 1928.

64. Michelet, Jules, The Insect. London: T. Nelson and Sons, 1875, 368 pp. Translated by W. H. D. Adams.

65. Munro, J. A., and Hazel W. Riddle, Insect Pests of Trees and Gardens. Fargo, No. Dakota: No. Dakota Agr. College, Agr. Exp. Sta. Circular 42, April 1930, revised Feb. 1933. 63 pp.

66. O'Kane, Walter C., Injurious Insects. New York: The Macmillan Co., 1912.

67. Packard, A. S., A Guide to the Study of Insects. New York: Henry Holt and Co., Boston; Estes and Lauriat, 1878, sixth edition.

68. Packard, A. S., Our Common Insects. Boston: Estes and Lauriat, n. d.

69. Parrott, P. J., and H. Glasgow, The Radish Maggot. Geneva, N. Y.: Agr. Exp. Sta. Bul. 442, November 1917. pp. 693-715 inc.

70. Peairs, Leonard Marion, Insect Pests of Farm, Garden, and Orchard. New York: John Wiley and Sons Inc., 1941. (London, Chapman and Hall, Ltd.).

BIBLIOGRAPHY, CONT'D.

71. Pettit, R. H., Insects Infesting Golf Courses and Lawns. E.Lansing, Mich.: Michigan State Col.of Agriculture and Applied Science Ext. Bul. 125, June 1932. 11 pp.

72. Pettit, R. H., Common Pests of Field and Garden Crops. E. Lansing, Mich.: Mich. State Col.of Agriculture and Applied Science, Agr. Exp. Sta. Special Bul.183, revised, April 1933.79 pp.

73. Pettit, R. H., Control Methods for Insects of the Kitchen Garden. E. Lansing, Mich.: Michigan State Col. of Agriculture and Applied Science, Extension Bul.117, revised,May 1934.19 pp.

74. Pettit, R. H., June-Beetles or White-Grubs in Michigan. E. Lansing, Mich.: Michigan State Col. of Agriculture and Applied Science, Agr. Exp. Sta. Circular Bulletin 132, revised, April 1937. 10 pp.

75. Phillips, W. J., and Henry Fox, The Rough-Headed Corn Stalk Beetle. Washington, D. C.: U. S. Dept. Agr. Bul. 1267, Oct.14, 1924. 34 pp.

76. Pierce, W. Dwight, "Some Hypermetamorphic Beetles and their Hymenopterous Hosts," The University Studies of the University of Nebraska, 4:153-190. Lincoln, Neb.:Published by the University, 1904.

77. Sanderson, E. Dwight, and C. F. Jackson, Elementary Entomology. Boston: Ginn and Company, n.d. (Copyright 1912.)

78. Sanderson, E. Dwight, and L. M. Peairs, School Entomology. N.Y.:John Wiley and Sons, Inc. n.d. (copyright 1917) 356 pp.

79. Schoene, W. J., The Cabbage Maggot: Its Biology and Control. Geneva, N.Y.: New York Agr. Exp. Sta. Bul. 419, March 1916,pp.99-160 inc.

80. Scudder, Samuel Hubbard, Every-Day Butterflies. Boston and N.Y.: Houghton Mifflin Company, 1899.

81. Seymour, E. L. D., editor, The Garden Encyclopedia. N.Y.: Wm. H. Wise & Co., 1936.

BIBLIOGRAPHY, CONT'D.

82. Sim, Robert J., Characters Useful in Distinguishing Larvae of Popillia japonica and other Introduced Scarabaeidae from Native Species. Washington, D. C.: U. S. Dept. Agr. Circular 334, Dec. 1934. 20 pp.

83. Smith, John B., Economic Entomology. Philadelphia and London: J. B. Lippincott Co., Second Revised Edition, copyright 1906, 475 pp.

84. Stawell, Mrs. Rodolph (Margaret Key), Fabre's Book of Insects. (Retold from Jean Henri Fabre, Souvenirs Entomologiques, translated by Alexander Teixeira de Mattos) New York: Tudor Publishing Co., n.d. (copyright 1921.) Seventh Printing, Oct. 1937.

85. Stone, W. E., et al., Control of the Celery Leaf-tier in Florida. Gainesville, Florida: Univ. of Florida, Agr. Exp. Sta. Bul. 251, July 1932. 23 pp.

86. Sweetman, Harvey L., The Biological Control of Insects. Ithaca, N.Y.: Comstock Publishing Co. Inc. 1936.

87. Teale, Edwin Way, Grassroot Jungles. N.Y.: Dodd, Mead, and Co., 1937.

88. Treherne, R. C., Root Maggots and Their Control. Ottawa, Canada: Dom. of Canada, Dept. Agr. Pamphlet 32 n.s., April 1923. 8 pp.

89. Treherne, R. C., Wireworm Control. Dom. of Canada, Dept. Agr. Pamphlet 33 n.s., April 1923. 6 pp.

90. Trowbridge, P. F., Experiment Station Progress. Report for the Biennium July 1, 1925 to June 30, 1927. Fargo, No. Dakota: No. Dakota Agr. College, Agr. Exp. Sta. Bul. 217, March 1928. 102 pp.

91. Walton, W. R., How to Detect Outbreaks of Insects and Save the Grain Crops. Washington, D. C.: U.S. Dept. Agr. Farmers' Bul. 835, Issued June 1917, revised Jan. 1924. 24 pp.

92. Ward, John J., Insect Biographies with Pen and Camera. N.Y.: Frederick A. Stokes Co. n.d.

BIBLIOGRAPHY, CONCL'D.

93. Webster, R. L., Potato Insects. Ames, Iowa: Iowa State Col, of Agricultural and Mechanic Arts, Agr. Exp. Sta. Bul. 155, 1915, pp.359-420.

94. Webster, R. L., and C. N. Ainslie, Pale Western Cutworms in North Dakota. Agricultural College, No. Dakota: Agr. Exp. Sta. Bul. 179, Apr. 1924. 24 pp.

95. Weed, Clarence Moores, Life Histories of American Insects. N. Y.: Macmillan Co., 1897.

96. Weigel, C. A., Calcium Cyanide as a Fumigant for Ornamental Greenhouse Plants. Washington, D. C.: U. S. Dept. Agr. Dept. Circular 380, April 1926.16 pp.

97. Weigel, C. A., and Wm. Middleton, Insect Enemies of the Flower Garden. Washington, D. C.: U. S. Dept. Agr. Farmers' Bul. 1495, issued Aug. 1926, revised June 1927. 54 pp.

98. Weigel, C. A., and E. R. Sasscer, Insects Injurious to Ornamental Greenhouse Plants. Washington, D. C.: U. S. Dept. Agr. Farmers' Bul. 1362, 1923. 81 pp.

99. Whitcomb, W. D., The Carrot Rust Fly. Amherst, Mass.: Mass. State Col. Agr. Exp. Sta. Bul. 352, May 1938. 36 pp.

100. White, W. H., and S. P. Doolittle, A Victory Gardener's Handbook on Insects and Diseases. Washington D. C.: U. S. Dept. Agr. Miscellaneous Publication 525, Feb. 1944, slightly revised July 1944. 30 pp.

101. Wood, J. G., Insects at Home. N. Y.: Charles Scribner and Company, 1872. 670 pp.

BOSTON UNIVERSITY
1 1719 02571 9479

ESS BINDER
ODUCTS INC.